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PLATE ILLUSTRATIONS.

SOME NOTES ON NUT GROWING IN THE NORTHERN UNITED STATES.

By Howard Spence.

The application of scientific horticultural practice to nut culture in the United States, as distinguished from the cropping of individual or grouped seedling trees, is of comparatively recent date. Yet so rapid has been the growth of what have become well organised nut industries that they are now supported by five vigorous Associations,* in addition to a further nine† which are more specifically identified with interests confined to the southern States by climatic limitations.

The present notes however refer only to certain sections of the subject which may possibly be of more direct interest to pomologists in this country, and are confined to a review of developments in relation to some of the Walnuts, Hazel nuts and Chestnuts, and their varieties.

The Persian Walnut.

Commercial walnut interests in the United States are as yet practically confined to the west and mainly to California, although Oregon is also becoming a factor, having in 1921, over four thousand acres of walnut groves, of which about one-third were then below bearing age.

The history of the development of walnut culture in California is an interesting one. Probably the earliest planting, though never extensive, dates from the time of the Franciscan Missions (1769 onwards) but the first substantial growth followed the introduction of a superior type of seedling trees derived from a sackful of nuts which were believed to have come from Chile. From the thousand or so seedling trees obtained from this source in 1868 their grower, Joseph Sexton, planted an orchard of about two hundred and fifty trees at Goleta in Southern California and, of these, some sixty trees yielded nuts of the so-called Soft shell type, the remainder being hard shelled. Of twenty four trees raised later from these soft shelled trees twenty one closely resembled the parent types, three being very distinct improvements and including the two named varieties "Santa Barbara Soft Shell" and "Improved Soft Shell."

* California Walnut Growers' Association, Northern Nut Growers' Association, Western Nut Growers' Association, Oregon Walnut Association Co-operative, California Almond Growers' Exchange.

† National Pecan Growers' Exchange, and the following Associations: National Nut Growers, National Pecan Growers, Georgia-Florida Pecan Growers, South-east Georgia Pecan, Texas Pecan Growers, Alabama Pecan Growers, Oklahoma Pecan Growers, Southern Pecan Growers.

Seedlings from these original Soft shell trees constitute the basis of several existing southern groves and naturally have given rise to all intermediate types of nut between the typical Hard and Soft shells.

In common with many fruit trees the walnut cannot be relied upon to breed true to variety and in both quality and yield seedling groves vary greatly. At the same time it is quite clear that, not infrequently, general type similarities are transmitted in respect of the nut, tree configuration, lateness or earliness of leafage and blooming and other points. In France two or three varieties are held, broadly, to breed true, *e.g.*, Noix fertile (*Juglans regia præparturiens* or *fertilis*) Noix à cerneau rouge (*J. r. rubra*) and, to the extent of about one-third of the seedlings, Gourlande, a superior variety of *J. r. maxima.*

In northern California the industry was practically originated in the early seventies from the introduction by Felix Gillet, of Nevada City, of scions and nursery stock of many of the best French varieties. Mr. Gillet also successfully experimented with seedlings from French stock with the object of developing improved varieties specially adapted to the new environment. These introductions of Messrs. Sexton and Gillet form the parent stock of practically the whole of the existing walnut trees in California, the crop from which in 1889 amounted to about two thousand (short) tons, in 1909 to nine thousand, and in 1919 to twenty eight thousand tons. The 1921 crop was poor in both quality and quantity—some eighteen thousand tons—owing to spring frosts and cold, a hot summer and early autumn rains. The crops of 1922 and 1923 were also below normal for the acreage and amounted to about twenty five thousand tons in each case.

In recent years the planting of seedling trees for commercial purposes may be said to have been entirely substituted by that of grafted or budded stock, As might however be expected, from among the very large number of seedling trees in the State it has been possible to select many which have proved themselves to be worthy of propagation. Among seedling walnuts so developed may be mentioned Placentia, one of the best southern California nuts and forming the major portion of the annual "budded" crop, Prolific, which comes into heavy bearing at a very early age, and Santa Barbara, typical of the variable Soft shell.

The varieties originated by Felix Gillet include Chase, San José (a Mayette seedling) and Concord. Other nuts of high grade are Eureka (a superior nut of the Placentia type but reputedly less subject to walnut blight) Ehrhardt, Payne and Willson ; and the original French Franquette (pre-eminently) and Mayette nuts and others still form standard varieties in California. A point of interest is the fact that a number of the locally developed California Walnut varieties show, in the new environment, a distinct increase over the normal in the proportion of carbo-hydrates they contain. The Eureka, Franquette, Mayette,

Payne and Concord are usually sold under their individual names, other grafted or budded varieties as "budded"—typically represented by the Placentia.

The following particulars relating to average nuts of some of the varieties named suffice to indicate different characteristics and relate to the nuts in the dried condition.

Variety.	Weight.	Size.	Kernel.
Chase	12 grms.	1.5″ × 1.2″ × 1.35″	47%
Concord	11 ,,	1.45″ × 1.2″ × 1.3″	50%
Eureka	14.5 ,,	1.75″ × 1.25″ × 1.3″	47%
Franquette ..	12 ,,	1.75″ × 1.25″ × 1.3″	46%
Placentia ..	10.8 ,,	1.6″ × 1.2″ × 1.3″	50%
Prolific	12 ,,	1.7″ × 1.3″ × 1.35″	50%
San José ..	11.1 ,,	1.75″ × 1.44″ × 1.5″	46%

Average cracking tests on the 1922 Oregon crop gave the following results: Franquettes, 48 per cent. kernel; Budded Seedlings, 46 per cent.; No. 1 seedlings, 41 per cent.; No. 2 Seedlings, 40 per cent.

The California walnut industry largely centres in the counties of Los Angeles, Orange, Ventura and Santa Barbara, and, in locally suitable areas, extends about one hundred miles north and south of this district and inland some twenty five miles from the coast line. At the present time walnut growing is extending considerably beyond the old limits. This applies particularly to central and northern California and to the interior valleys. Late spring frost may cause much injury to the crop and low frosty sites are avoided. On the other hand loss from sunburn is experienced in many of the interior valley orchards. In the whole State there were in 1921 approximately eighty five thousand acres of walnut groves of which about sixty thousand were in bearing. The hundred thousand mark has now been passed and the present annual rate of extension is some six thousand acres newly planted, and about four to five thousand coming into bearing.

The industry is organised in local co-operative associations which are mainly affiliated with a central body, the California Walnut Growers' Association. The local bodies own and operate their own drying, grading, bleaching,* cracking and packing plants, dealing on the average with six to seven hundred tons annually but the largest of which is capable of handling up to three hundred tons of walnuts daily. In the State there are between forty and fifty of these plants. The C.W.G.A., a non-profit organisation, forms the central selling agency and including very considerable outlay on selling propaganda and research, operates at a net cost to the growers of about five per cent. on the sales. Its membership

* Usually with dilute sodium hypochlorite solution.

is between three and four thousand and it disposes of about four-fifths of the whole crop. The output of the cracking plants, which operate for about six months out of the twelve, is now largely put up in hermetically sealed vacuum tin containers carrying about half a pound of shelled nuts, or in vacuum glass jars, and forms a very attractive and long keeping pack. Shells are converted into a good grade charcoal, equal in weight to about one third of the original, for chicken and pig feed and other purposes. The Association has, in short, gradually built up a highly developed co-operative organisation which has raised the quality of its product to a very high standard (the crop is strictly graded, light weight poorly filled nuts being removed by suction fans and the rest sorted mechanically and by hand selection over endless belts, up to a standard of about ninety four per cent. sound nuts) and concurrently organised systematic scientific research into all questions affecting the life history of the walnut under Californian conditions.

Close co-operation is maintained with the University of California Experiment Station. One of the highest authorities on walnut culture, Professor R. E. Smith of the California State Agricultural College, has been retained by the Association for a number of years on walnut problems and this far-seeing policy has already been more than justified. One result may be cited in illustration. As a result of careful research into the best methods of dealing with pests affecting the walnut the use of insecticide dust in place of spray has been gradually developed and proved to be highly advantageous and capable of successful employment with trees approximating forest size. The composition of the most active powder and its application have been under thorough investigation by Professor Smith for some years and the final product, "Nico-dust" (a mixture of hydrated lime, kaolin and nicotine sulphate) is now also finding increasing use on other crops. The percentage of nicotine is varied for the particular purpose in view and the dust is also prepared in admixture with finely divided lead arsenate, sulphur, dry Bordeaux mixture, and other components for special purposes. The Field Department of the Association, at present under the direct supervision of Professor L. D. Batchelor, is carrying out extended pruning and fertilization trials in different localities (in co-operation with the University) to determine unsettled questions relating to these points. Recent work on the prevention of discolouration of the nut kernel during harvesting operations through mould development has been of considerable assistance to the industry. A well-organised and supported State Agricultural service is obviously of the highest value to the California walnut growers, as also to the horticulturists of any State of the Union.

Until about 1904 commercial nuts were almost entirely the product of seedling trees, mainly of the Soft shell type. These trees commence to bear small crops about eight to ten years after planting. During the last eighteen or

J. californica (southern type).
J. californica (var. hindsii).
J. nigra (Marble Hill Park).
J. nigra × *J. californica* (Royal).
J. nigra × *J. regia* (Paradox).

J. sieboldiana × *J. cinerea.*
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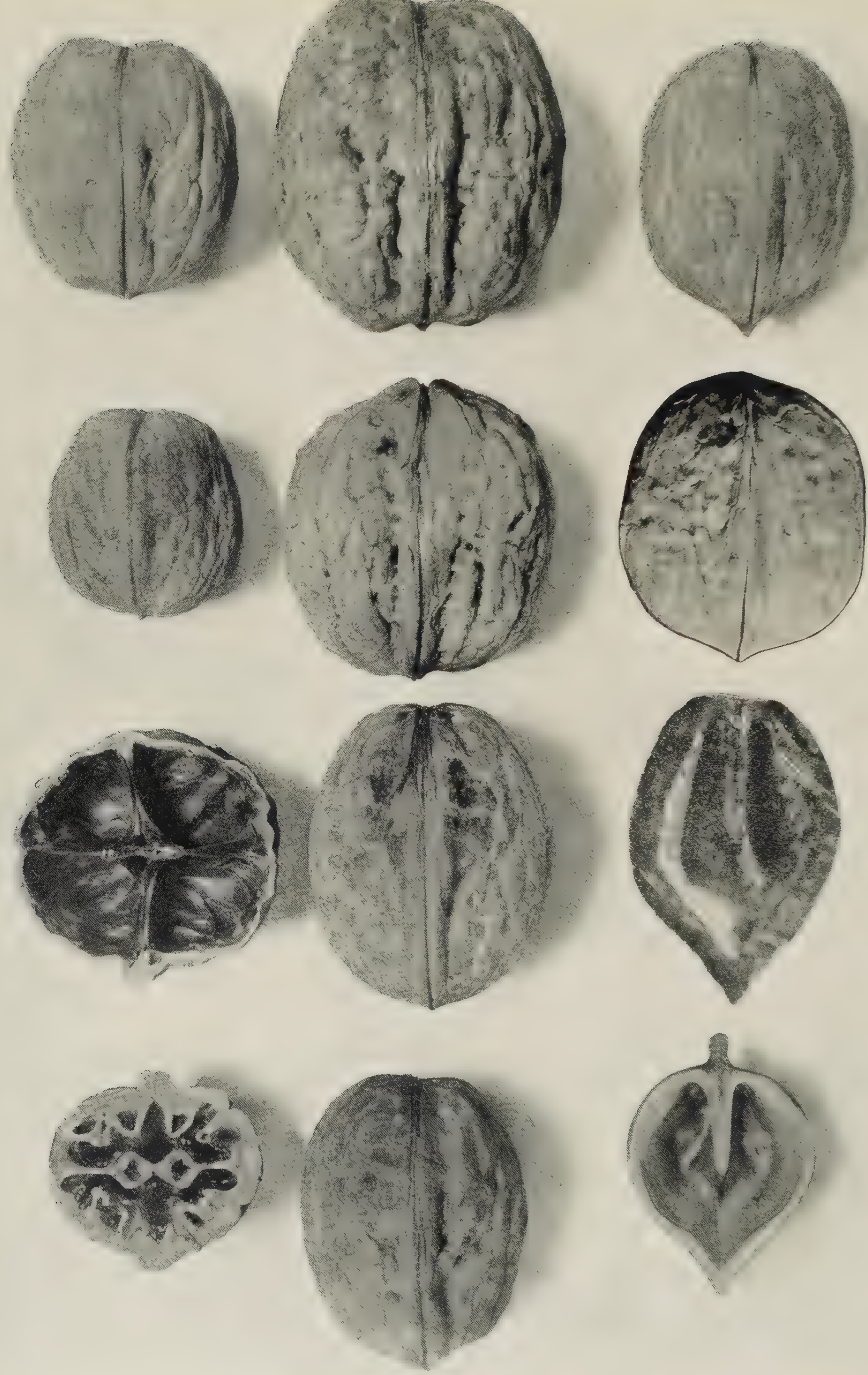
(All nuts natural size.)

Castanea dentata.
van Fleet hybrids.
Corylus americana.
Castanea mollissima.
Castanea pumila.
Corylus avellana (Du Chilly).
Corylus avellana (Barcelona).
Corylus colurna.



Mayette (*J. regia*).
Fertile (*J. regia praeparturiens*).
Chinese Seedling, cross section (*J. regia*).
Himalayan wild type, cross section (*J. regia*).

Gourlande (*J. regia maxima*).
Bannut (*J. regia maxima*).
Oval, Chile (*J. regia*).
Franquette (*J. regia*).

Sorrento (*J. regia*).
Placentia (*J. regia*).
J. mandshurica, section.
J. cordiformis, section.

(All nuts natural size.)

twenty years however, by far the major portion of commercial plantings have been budded or grafted trees, principally upon stocks of the northern California Black walnut, *Juglans californica*, var. *Hindsii*. Hybrids between this and the eastern Black walnut, *J. nigra* (*Royal*, Burbank), and either of the two Blacks and *J. regia* (*Paradox*, Burbank), which give stocks of extraordinary growth vigour, are also used, and, to a trifling extent, those of *J. nigra*.

Walnut grafting or budding is more difficult than that of most fruit trees and success has until lately resided less in the actual method adopted than in the skill and practice of the operator. So far back as 1818, Thomas Andrew Knight made very interesting and instructive observations thereon.* The methods in general use are illustrated and described in the publications of some of the Nut Associations earlier named and in particular those of the Northern Nut Growers' Association, and are also detailed in excellent illustrated State and Government monographs, *e.g.*, "Walnut Culture in California"† (R. E. Smith) Bulletin 231, Agricultural Experiment Station, University of California, 1912 : The Persian walnut industry of the United States (E. R. Lake), U.S. Dept. of Agriculture, Bur. of Plant Ind. Bulletin, No. 254, 1913. "Walnut Culture in Arizona" (J. J. Thornber), University of Arizona Agricultural Experiment Station, Bulletin No. 76, 1915, and, for French methods, "Le Noyer" (F. Lesourd), Librairie Agricole de la Maison Rustique, Paris, 1920, may also be consulted in this connection.

A later publication of the California Agricultural Experiment Station, "Walnut Culture in California" (L. D. Batchelor) Bulletin No. 332, June, 1921, brings the subject up to date for that part of the world.

Within the last three or four years however, probably the most important recent advance in the art of asexual reproduction has been worked out by R. T. Morris, a leading New York surgeon and the first president of the N.N.G. Association, who has long been keenly interested in nuciculture. Developed primarily to overcome the special difficulties encountered in the propagation of some nut trees—the Hickories in particular—Dr. Morris' methods are equally applicable to other species and promise very materially to facilitate and extend the operations of grafting and budding. Dr. Morris has summarised his results in book form to which reference should be made for full detail.‡ Briefly, the employment of a special light pervious grafting wax with complete covering of the part of the stock affected and of the scion, in conjunction with a number

* Upon the propagation of varieties of the walnut tree by budding, Transactions of the Horticultural Society of London, Vol. III., p. 133 seq.
Upon grafting the Walnut Tree. (Ibid.) Vol. I., 2nd series. April 17th, 1832.

† Now out of print but available from the library of the Ministry of Agriculture and Fisheries.

‡ "Nut Growing," R. T. Morris. The Macmillan Co., London and New York, 1921 (revised, 1924).

of special manipulative methods, have not only greatly increased the percentage of " takes " but have lengthened the grafting period by some couple of months. The volume generally is most stimulating and suggestive. A slight modification of one of his methods as applied to some sub-tropical fruit trees has recently been described in the " Journal of Heredity."*

Californian budded or grafted walnuts normally have a value of some two or three cents per lb. in excess of high grade Soft shell seedlings and many of the old seedling trees have been top-worked to better varieties. Budded trees come into profitable bearing some couple of years sooner—at from six to eight years of age—than the seedling, the trees grow faster and bear more heavily and the crop is of higher grade. Planting distance, as experience has accumulated, has gradually increased: fifty feet apart, seventeen to the acre, is now regarded as a minimum and the tendency is still further to increase the space, and even up to one hundred feet has been recommended. Many groves have recently been planted in rows sixty feet apart with a space of thirty feet between the trees in the rows. The rows are thinned out after ten to fourteen years (given sufficient moral courage) and up to this time will give a yield of nearly double that of an original stand of sixty by sixty feet. Clean cultivation is usually practiced, and winter cover crops (clover, vetch or other leguminous species) planted after gathering the crop and ploughed well under about March or April, are much used: irrigation at the rate of twelve to twenty four acre-inches per annum is widely employed, and also inter-cropping in early years.

The yield varies in different groves according to situation, age and character, from about three hundred lbs. per acre up to two thousand or over, with an average of about nine hundred lbs.† Some of the older established groves are among the most profitable: one of twenty six acres, planted in 1888, twelve to the acre, sixty feet apart, has given an average crop during the past four years of nineteen hundred and forty lbs. per acre. Returns from over nine hundred groves in 1918, gave nine hundred and forty nine lbs. per acre for trees over twelve years of age and five hundred lbs. per acre for trees between seven and twelve years. General culture and harvesting costs (pre-war) may be taken at about fifty five dollars per acre. At present, on the basis of eight hundred lbs per acre, it is about one hundred dollars. The average price realised has fluctuated considerably and shows a material advance during the past few years. The price of No. 1 Soft shell seedling walnuts in California for the years 1909-1920 averaged 18.2 cents per lb. in comparison with 21.3 cents for "budded." Competition is severe from European walnuts imported mainly from France,

* December, 1923.

† The famous Payne tree in San José, with a height of 75 feet and 80 feet spread, a large black Walnut planted in 1880 and grafted over to the Santa Rosa variety in 1894, gave a crop in 1919 (a very good year) of about 850 lbs., but this is an isolated tree in the barnyard.

Italy and Spain, and also from nuts from Chile* and China, the latter supplying almost as many as France and increased tariff protection has recently been obtained.† In 1922 foreign importations were a little less than the home production and were sold at an average price, wholesale, of about fifteen cents per lb. as against about twenty two cents for Californian nuts. This difference may be largely attributed to lack of uniformity in the grading of foreign walnuts. Per contra, the foreign shelled walnuts, owing to more rapid crop gathering methods, are practically all lighter in colour than the American "cull" kernels and have a corresponding advantage.

The following figures of estimated costs and yields are extracted from Bulletin 332, 1921, California Agricultural Experimental Station, as indicative of what may be expected from a competently run grove in California.

Yield per acre	1,200 lbs.	
Valuation per acre	$1000.00	
Gross income		$196.44
Annual cost of operation	$60.00	
Annual cost of packing and marketing ..	$24.00	
Interest at 4%	$40.00	
		$124.00
Profit, per acre, in excess of interest ..		$72.44

Singularly little has been written on the pollenation of the walnut—apart from the subject of hybrids between the species. The walnut is monœcious, the pistillate flowers being borne on the new wood developing in the spring from the terminal buds of the previous seasons growth and the staminate on the old wood. The pollen is wind carried and it is at least probable that interplanting of different varieties would give the maximum chance for the provision of pollen at the most active period of receptivity. This might lessen the risk of "off" years in bearing. It is known that some varieties, either from imperfect development of pistillate or staminate flowers, or from the fact that they do not mature at the same time on the same tree, not infrequently fail to set their crop and it has been suggested that two or more varieties blossoming about the same time should be planted together.‡ Cross fertilization may take place with trees as far apart as two hundred yards. In California the *Paradox* cross between

* Chilian nuts, from south of the equator, ripen in March and April and come in as "new crop" nuts six months earlier than the Californian.

† From two to four cents on unshelled walnuts and from four to twelve cents on shelled.

‡ The Persian Walnut Industry of the U.S. E. R. Lake, U.S. Dept. of Ag., Bur. of Plant Ind. Bulletin 254, (1913), p. 78.

J. regia and *J. nigra* (and which may also arise from crosses between *J. regia* and *J. californica*, *J. major* (Arizona black walnut) and *Paradox* and *Royal* hybrids themselves) in many cases carries very large quantities of catkins and pollen, although its own pistillate flowers are not pollenized freely and give few nuts. In a few instances, although not normally, where it stands near to *regia* trees it is known to bear freely. The *Royal* hybrid (*J. nigra* × *J. californica*, and also crosses between the Blacks and second or later generation hybrids) on the other hand, is not only very precocious but is probably the most prolific walnut known. The fact that in some years a favourably placed tree will give practically all hybrids while in other years the nuts give almost entirely straight seedlings is presumably accounted for by variation in blooming time from year to year.*

Walnut Blight or Bacteriosis arising from infection by a bacterial organism, *Pseudomonas juglandis*, Pierce, is one of the most serious diseases affecting the walnut in California. It appears to have been first noticed about 1891 in Los Angeles. The young succulent growth is attacked during the earlier months of the year and shows black sunken spots or canker but the disease is checked as it becomes more woody in character, and the parts affected tend to heal. Some twigs are killed back from the tips and many small nuts attacked drop when one-eighth to one-half inch in diameter, others showing black spots which may ultimately reach the kernel and ruin the nut. Many attempts have been made by spraying with various fungicides and otherwise to control the pest, which chiefly affects trees in regions in which a high degree of atmospheric moisture is prevalent in the spring and early summer months, but so far without success. The amount of damage done to the crop varies largely from year to year, but it has been estimated that over a series of years not less than half the normal crop of seedling trees in southern California was lost through this cause. Normally the effects of the disease are surmounted by vigorous trees and the growth and life not permanently affected. This disease, although not the same, has many features of resemblance to that arising from the fungus which attacks walnuts in Europe, *Marsonia juglandis* (Anthracnose). This disease is known to affect the leaves of *J. nigra* and *J. cinerea* in the eastern States, and in France may seriously affect the walnut crop in certain valleys if it starts early in the season. In California late blooming trees largely escape serious blight infection and, in addition, certain trees have shown a marked degree of resistance. While spraying has generally failed to eradicate the trouble a certain measure of improvement at least has in some cases attended the operation, insufficient however in amount to warrant the cost of application. This has also been the experience in France (employing Bordeaux mixture) with *Marsonia*. Prevalence of the disease has

* Walnut Culture in California. Bulletin 231, p. 155.

THREE MONTHS' GROWTH AFTER TOP-WORKING.

WALNUT CURING IN THE OPEN.

J. CALIFORNICA SEEDLINGS IN FIRST YEAR'S GROWTH.

WALNUT GRAFTING IN THE NURSERY ROW: OREGON.

been a potent factor in the re-working of California seedling trees to more resistant as well as more fruitful varieties. The trouble varies considerably in different years and attention is now being concentrated on the selection or breeding of resistant varieties as affording the most hopeful prospect.

Melaxuma of the walnut, a comparatively new disease in California and under observation since about 1909, is caused by infection of a fungus, *Dothiorella gregaria*, and results in the formation of black sunken cankers in the trunk and larger limbs (particularly in the crotches) and sometimes in the sudden wilting of the smaller branches. From the surface of the cankers a black watery substance oozes, giving the appearance of a patch of tar. Cutting out the cankers in the early stages and disinfection with Bordeaux paste is the remedy at present employed. The same fungus similarly attacks a native willow. It is not known to cause serious injury in Europe.

Winter injury or Die-back which is shown by the sudden death of the tops of the trees, and has at times caused considerable damage on the Pacific Slope, is attributable at times to insufficient maturity of new growth by the end of the summer (promoted by late summer irrigation or a too high water-table) but the principal cause appears to be too low moisture content of the soil during winter months. The presence of excess alkali in the soil or irrigation water is also a contributing cause. Late autumn or early winter irrigation, in December or January, has been found to be an effective preventive.

Pests seriously affecting the walnut are Aphis (*Chromaphis juglandicola*), Red spider and Codlin moth. In a season of average prevalence the aphis, if unchecked, is estimated to reduce the yield by some seventy to one hundred lbs. per acre. It may also possibly assist in the spread of Bateriosis. Codlin moth was observed in Californian walnut groves about 1909 and infestation became general; in France it is said to be responsible for a very considerable annual loss of crop. Effective control of these pests may be secured by the use of nicodust, or nicodust and arsenate of lead. The earlier method of spraying with the necessary liquid cost about forty to sixty cents per tree but with the use of the most modern type of power dust-blower twenty to thirty acres per day may now be covered at a cost of fifteen to twenty cents per tree. Treatment is usual between the end of May and of June and the quantities employed up to twenty five gallons of liquid or two to eight lbs. of dust. The latter is preferably applied during the earlier part of the day in still moist air.

In the eastern States the cultivation of the Persian walnut, where it has been grown for some centuries, is receiving increasing attention. Numerous fine seedling trees in widely separated areas prove its adaptability in many places, but the records of failure from inability, particularly in early growth, to withstand the extremes of winter cold and spring frosts necessitate caution and experiment before engaging in extensive planting. Sufficient success has

nevertheless already been attained to warrant continued trial. Late blooming varieties are being sought to escape late frost and to benefit possibly from the pollen of *J. nigra* and *J. cinerea.* As in the west, grafting upon native stocks, in this case *J. nigra*, is almost universal. Walnut blight is generally present but apparently not in a severe form. The following locally grown seedling varieties are being propagated: Hall, Rush, Holden and Nebo; and Franquette (Vrooman) and Mayette (Wiltz) of more recent European derivation.

The north-eastern States are the principal hunting ground of the Northern Nut Growers' Association. The aims of this Association are scientific and educational and it has done much pioneer work not only in extending general interest in nut culture but, through its membership, in experimental work to determine what species and varieties of nuts are capable of acclimatisation in the northern States east of the Rockies. It has also done very valuable work in the indentification and propagation of the best varieties of indigenous and introduced species. Until comparatively recently few records were available of the Hickory, Black walnut, Butternut, Persian walnut, northern Pecan and Japanese Heartnut (*J. cordiformis*) trees bearing exceptional quality nuts which may be found up and down the country, but systematic investigation has already led to the identification of quite a number of superior types of these and other nuts. As in the western States so in the eastern, it has long been recognised that apart from the vitally important field offered by seedling trees for the selection of improved varieties, the future lay with grafting or budding, selection of the most suitable stocks, and in breeding for improvement in flavour, size, cracking quality, percentage of kernel and productivity.

This Association has naturally concentrated its attention upon native nuts, the Black walnut, the Hickories, northern Pecans and, more lately, the Butternut. The eastern Black walnut is native over a wider area than any other northern nut. A power machine has recently been devised for cracking these nuts which gives nearly half the output in halves, the balance being in smaller pieces of kernel. If cracked within two or three months of gathering the proportion of whole halves is greater. The ordinary run of nuts vary in size from three-quarters of an inch to two-and-a-half inches. The kernel, apart from home use, finds considerable application in confectionery and already some eight or nine named varieties are being grown on account of flavour or superior cracking quality—the prime consideration with this nut. Three may be mentioned: The Thomas (from Pennsylvania), the Stabler (Maryland) and the Ohio (neighbourhood of Toledo). Good nuts yield twenty to twenty five per cent. kernel on the total weight which varies between fifteen and twenty and, exceptionally, up to thirty grams; cracking pressure one hundred and ten to three hundred kg. Planting is recommended at sixty to eighty feet apart with intercropping in early years. The nuts of this tree ripen in England in

warm summers: the writer has raised a number of vigorous seedlings from those of the very fine eastern Black walnut growing in Marble Hill Park, Twickenham, which is illustrated in "Trees of Great Britain and Ireland" and forwarded one or two to the head keeper in the hope of perpetuating this fine tree, now past its prime, and there must be many more suitable localities where this would be the rule rather than the exception. In a favourable season there should be a possibility at least of the formation of the *Paradox* cross in the nuts on this tree or the comparatively near-by *regia* trees. In California however, *nigra* trees usually bloom much later than *regia*.

The Japanese walnuts, *J. sieboldiana* and *J. cordiformis* (the latter now generally taken to be a variety only of the former) grow vigorously in the States both north and south, and bear prolifically at a comparatively early age. *J. cordiformis* will there grow well where *J. regia* is quite unable to withstand the winter. They are stated to bear with great regularity in British Columbia. The proportion of kernel to the whole nut (twenty five to thirty per cent.) is greater, in good varieties, than in the case of the Black walnut and in the varieties propagated the kernel usually drops out whole on cracking. Weight of nut five to nine grams.: cracking pressure required, about eighty to one hundred and eighty kg. It occasionally matures its nuts at Kew. The interior shell structure of *J. cordiformis* approximates closely to that of the native Butternut, *Juglans cinerea*, and the two species hybridize with extreme facility, giving rise to nuts of all grades of variation between those of the parents.

A number of *J. cordiformis* × *J. cinerea* hybrids have yielded superior strains of nut but they generally approximate more closely to the *cinerea* stock. Some of these hybrids are now being propagated asexually in the eastern States and have given rise to the term "Butterjaps."

It is of interest to note in this connection that many of the finer nuts sent in year by year to the prize contests of the N.N.G.A. for standardisation are gathered from trees which show undoubted indications of hybrid character in bud, leaf and nut. Some of the Hickory nuts receiving the highest classification are clearly hybrids between the Shagbark hickory (*Carya ovata*), the Bitternut (*C. amara*) and the Shellbark (*C. laciniosa*). A number of varieties of outstanding size and good cracking qualities have been located and are being propagated. One or two also of the so-called northern Pecans which are now being tried out considerably north of the usual pecan belt clearly show union between the Shellbark hickory and the Pecan (*C. pecan*).

The Pecan itself, one of the finest of native American nuts, requires a longer growing season and more warmth than is found in this country or even France, but the limitations of its hybrids are largely unexplored. Hybrids between related species may not only lead to the production of nuts of excellent quality but also considerably extend their range.

The Butternut has a wide range in the eastern States and goes further north than *nigra*. While the proportion of kernel to total weight is probably the least of any of the commercial nuts (fifteen to twenty per cent.), the simpler internal shell structure generally allows easier extraction of the kernel than do *sieboldiana* or *nigra*. The flavour of this nut is preferred by some to that of any other and one or two varieties are now being propagated by grafting. Average weight of good nuts ten to twenty grams: cracking pressure two hundred to three hundred and fifty kg. In this country it rarely fruits effectively.

The Manchurian walnut, *J. mandshurica*, with a fruit not unlike that of the Butternut, is a promising subject for experimentation by selection and hybridizing in this country, being perfectly hardy and bearing well, and also *J cathayensis*, with a very thick shelled but good flavoured nut and which begins to bear when eight to ten feet in height. *J. mandshurica* ripens its fruit two to three weeks earlier than *J. regia*.

A movement for the employment of suitable nut bearing trees for lining the national highways is receiving some measure of support in the United States. Michigan already has a law providing for, *inter alia*, the use of nut trees in this connection. The eastern Black walnut, the Persian walnut (already used for this purpose in California) and the Tree hazels (*Corylus colurna* and *C. chinensis*) and others are receiving consideration.

Hazel Nuts and Their Varieties.

The effect of Hazel blight in the north-eastern States of America for many years prevented any substantial cultural development of *Corylus avellana* varieties, although in some localities its effect has not yet been felt and considerable plantings have recently been made. The fungus, *Cryptosporella anomala*, Sacc. and possibly also *Cytosporina*, has as its host plant in the U.S. *Corylus americana*, but apparently it does not attack the western Beaked hazel, *C. Rostrata* (*C. californica*) or is quite harmless. As is frequently the case, *e.g.*, with Chestnut blight in the far east, a very considerable degree of resistance has developed in the native species and the most serious effect is reserved for the new-comer, unprotected by any degree of gradually acquired resistance. As Dr. Morris has shown however, the control of Hazel blight in the eastern States is quite compassable with care. Although also affecting the smaller extremities the blight mainly attacks the stem and larger branches and appears as areas, which may be several inches in length in long standing or severe cases, of depressed bark overhung on the margins by thick healthy bark, the diseased area showing dark pustular fruiting spores at certain seasons. Cutting away the diseased bark during winter followed by an application of white paint or pine tar and careful pruning off and burning the smaller diseased branches and twigs suffices to keep the disease in check. Of *C. avellana* varieties, the Red

CALIFORNIA WALNUT GROVES.

Intercropping in early years (lettuce).
A leguminous cover crop before plowing under.
Full grown: showing necessity of wide spacing.

A WALNUT GROVE IN FULL BEARING: TREES 50 FEET APART.

WALNUTS AS STREET TREES IN CALIFORNIA.

Aveline is said to be much more resistant than other forms. The Turkish tree hazel, *C. colurna*, which has nuts of very much the same type as those of the American hazel is apparently immune and is being tested as a stock for *avellana* varieties. Dr. Morris has some promising work under weigh on this point. *C. colurna* which is perfectly hardy in this country and usually ripens its nuts in the southern counties, has been grown here at least since the seventeenth century and was then tried in the reverse way to that mentioned above *i.e.*, as scion on *avellana* stock. It grows to a height of sixty to seventy feet with a girth up to seven and half feet. The Chinese tree form, *C. chinensis* was introduced in 1900 and is growing well.

The following figures relate to the grade of European varieties grown in New York State and in the Pacific North-West.

Variety.	Region.	Average weight. grms.	Kernel. %	Cracking pressure. kg.
Medium (long) ..	N.Y.	2.2	41	46
Lambert (red) ..	N.Y.	2.3	35	42
Lambert (white) ..	N.Y.	2.2	40	60
Merveille de Bollwyller	N.Y.	2.5	37	49
Daviana	P.N.-W.	3.1	51	33
White Aveline ..	P.N.-W.	2.1	49	26
Barcelona ..	P.N.-W.	4.3	42	42
Noce Lunghe	P.N.-W.	4.8	42	79
Imperial	P.N.-W.	3.5	33	51

In comparison with the above the best variety of the American hazel (*C. americana*) so far recognised, the Rush, gives the following average :—Weight 2.1 grms., percentage of kernel 45, cracking pressure 39 kg.

The development of filbert culture in the western States is of very much more recent date than that of the walnut, and at present centres largely in the Willamette Valley in Oregon. Contrary to the earlier experience of the eastern States *Corylus avellana* varieties have from the first succeeded remarkably well in suitable sections. No trouble from blight has so far developed and the industry is rapidly growing ; the Federal Horticultural Board of the U.S. and the corresponding Canadian Board have been requested by the Western Plant Quarantine Board to take steps to protect western growers against the possible introduction of this disease by the necessary quarantine regulations.* The native western hazel grows most vigorously on the Pacific

* The State of Oregon has now established quarantine against all *C. avellana* varieties, and against *C. americana* east of the Province of Alberta and the States of Idaho, Utah and Arizona.

Slope and frequently develops a height of thirty to thirty five feet. This species has a very wide range and extends as far north as Labrador.

The varieties chiefly raised are the Barcelona (preponderantly), White Aveline (White Filbert), Du Chilly (nut practically identical with Kentish Cob), Imperial, Noce Lunghe (a large nut about 1 in. long and $\frac{7}{8}$ ins. wide of good quality). The Barcelona was introduced by Felix Gillet in 1871 under the name "Grosse Blanche d'Angleterre" and only later, in 1895, renamed by him Barcelona. More attention seems of necessity to be devoted to the subject of pollenizing than is apparently required in this country. Professor C. E. Schuster of the Oregon Agricultural College, who has devoted much study to the question of pollenation of the filbert, has come to the conclusion that practically all of the considerable number of varieties with which he has experimented are practically self-sterile. Unfortunately some of the best pollenisers are poor commercial varieties. Yields depend upon variety, age, and how pollenised. Some few examples may be cited. One tree five years old gave sixteen lbs. dried nuts, another better tree of the same age which had never suckered eighteen lbs., a Barcelona six years old twenty one lbs., another twelve years old forty one lbs. A ten year old tree produced fifty lbs., another thirteen years old fifty lbs., but these latter yields can only be expected from trees about twenty feet high and with a twenty feet spread. A three hundred tree orchard with trees from nine to eleven years old averaged ten to eleven lbs. per tree. As here heavy yield appears to go with hard pruning but the general conditions are obviously exceptionally favourable. Rich river bottom soil seems to be preferred.

One of the most experienced growers puts the varieties in the following order of merit. Barcelona (a long way ahead), Du Chilly, White Aveline: all three he holds to be self-fertile to a limited extent only and judicious spacing is recommended. Du Chilly is a perfect pollenizer for the Barcelona but not *vice versa.* The Daviana (Duchess of Edinburgh) is equally good for the Du Chilly and probably the Barcelona, but neither of the two latter, nor Red nor White Aveline, will pollenize the Daviana. This grower considers the Daviana to be the finest filbert grown provided a good pollenizer be found but at present practically its only function is that of a pollenizer for other varieties. The Avelines appear to pollenize the Barcelona and Du Chilly to a limited extent only and the latter do not reciprocate at all. From Red and White Avelines with Davianas as pollenizers full crops may confidently be expected. Bearing in mind the differing habit of the varieties—Barcelona, a rampant grower with approximately equal spread and height, Avelines at the same age about half that of the above, and Du Chilly intermediate between the two but compact and upright—he would recommend to the acre (approximately):—Rows twenty feet apart, ten rows east and west, eleven rows north and south: Daviana

pollenizers trees Nos. 5 and 10 in north and south rows 3, 6 and 9, and Du Chilly trees Nos. 2, 3, 7 and 8 in the same rows. This is six Davianas, twelve Du Chillys and ninety two Barcelonas to the block of one hundred and ten trees. Du Chillys in the absence of Barcelonas could be safely planted eighteen feet apart and the Avelines fifteen feet. An alternative might be, in a block of one hundred Avelines fifteen feet apart, Daviana, Nos. 4 and 9 in rows 4 and 8 with from 4 to 8 red Avelines in the same row; the latter appear to be good pollenizers for the White variety. Based on his actual experience he gives the following estimate of yields. One acre of No. 1 Barcelonas: at five years five hundred to a thousand lbs.; at six years ten to fifteen hundred lbs.; at eight years two to three thousand lbs.; at ten years three to four thousand lbs. and at twelve years four to five thousand lbs.

A considerable portion of the blocks planted to filberts in Oregon are seedlings and to these attention is being directed for the identification of any possibly superior varieties.

The development of suckers should be prevented by digging to the root at least twice a year for the first four or five years, cutting them off as close as possible and shaving the bark of the root where the sucker is attached to destroy dormant buds. A method which is stated to give good results in keeping this trouble in check is to place the rooted layer in the nursery row for a year and, when transplanting to the orchard, to cut off all of the original layer that is possible. The long slender roots are then pressed well down into the ground as deeply as the length of the root will permit and the main stem of the plant is raised well above its former position in the nursery. If any sprouts do happen to form they will then be above ground and may readily be rubbed off. Suckers for propagation purposes should not be raised from trees in the grove but from roots intended solely for this purpose. The following reasons are adduced for preference for the Barcelona in the North-West, on which nut growers are tending to concentrate. It is of good size and readily saleable, the short husk opening as it matures permits the nut to fall free (the nuts are not sold in the husk as is common here), it is the heaviest cropper and is free from the attacks of the bud mite to which both the Du Chilly and White Aveline are subject. The better growers float their crop to remove the empty shells and are thereby enabled to guarantee a 98 per cent. cracking test.

The only pest in this region is the Filbert mite, and some little trouble with moss is experienced. Occasional spraying with Bordeaux mixture or weak lime-sulphur to clean up the trees is recommended.

The experience of one of the largest growers of filberts in the eastern States (in Rochester, N.Y.) where nuts originally obtained from Germany are chiefly propagated (the principal varieties being Merveille de Bollwyller, White, Red and Medium-long Lambert, and Italian Red) corroborates that of the

Oregon growers ; he attributes his very successful cropping primarily to thorough pollenation from the number of varieties grown together and the use of such filberts as, *e.g.* Burkhardt's Zeller and Early Globe, which, although giving small nuts, are highly prolific catkin bearers.

Chestnuts.

The recent history of the American chestnut (*Castanea dentata*) is melancholy reading. Twenty years ago in the north eastern States it was one of the finest forest trees, to-day a large part of these forests and innumerable individual trees are dead or dying. Early in the present century, in the neighbourhood of New York, many chestnut trees were seen to be suffering seriously from some unknown pest. Investigation traced this to a fungus, *Endothia parasitica*, the mycelium of which spreads along the cambium layer and encircles the tree, bringing about its enfeeblement and death. In ten to fifteen years it had spread to some thirteen States and had decimated half the American chestnut forests, and is still extending its ravages. When only known to be present in ten States the loss was officially estimated, in 1911, at twenty-five million dollars. Its origin is traced to north Chinese imported stock as the disease is well-known in north-eastern Asia on *Castanea mollissima*. There however, probably in the course of centuries, a very considerable degree of resistance has developed ; in northern China, for example, trees may be found which have been attacked but have survived and largely repaired the damage. No such comparative immunity has as yet been shown in the American forest species and although some strain may eventually be found which will show sufficient resistance to survive (American trees vary much in the fight they put up against the disease) the remedy is probably to be looked for mainly in the direction of breeding a variety resistant to attack or in the introduction of other immune *Castanea* or *Castanopsis* species.

A large forest form, *C. Vilmoriniana*, growing to from eighty to one hundred feet high, from the interior of China, is now under trial at the Arnold Arboretum and at Glendale, Maryland. Horticultural exploration work, so effectively organised by the Bureau of Plant Industry of the U.S. Department of Agriculture has already brought to light several new species and some of these may prove to be not only resistant or immune to the blight but of good nut quality. New *Castanea* species have recently been chronicled from the mountainous regions of south eastern Asia where exploration work with this as one objective has been in progress for some time.

Diagnosis is complicated by the fact that young seedling trees up to eight to fifteen years old are not attacked, due no doubt to the smooth unfissured character of the bark. If wounded however, or inoculated, this temporary




GRAFTING OVER OLD WALNUT STOCKS TO GOOD VARIETIES.

Cleft or bark grafts inserted.
(Trunk whitewashed to protect from sunburn.)

Waxed scions protected by paper bags.

J. californica top-worked with "Ehrhardt."
(Two years' growth of scions.)

J. californica top-worked with "Ehrhardt."
(Two years' growth of scions [winter.])

ONE METHOD OF WALNUT GRAFTING.

A—Splitting the Stock. B—Scion in position.
C—Ready for waxing. E—A good union and root development.

non-susceptibility ceases. After infection has occurred it takes from one to ten years to kill the tree—the average duration of the disease being three to four years.

A very careful survey was made some years ago in the neighbourhood of New York under the ægis of the Bureau of Plant Industry, to ascertain if, in any areas, any successful resistance was being offered to the disease, and three areas were located in which at least a good fight was being waged by isolated groups. Not only have mature trees in these localities (growing in varying soils under differing conditions) shown unexpected resistance although surrounded by trees dead or dying from the disease, but following direct inoculation they have shown fungus growth only about a third or a quarter as fast as that on the ordinary chestnut. The group formation of these trees tends to support the view that the resistant character may be hereditable and this is still under investigation.

Although showing a rather greater degree of resistance the European species (*C. sativa*) succumbs equally with the native American species (*C. dentata* and *C. pumila*). Certain Japanese species are largely resistant and, so far at least as the nut is concerned, breeders are concentrating on hybrids between the Japanese (*C. crenata*) and the common Chinese species (*C. mollissima*), and the two forms of the native Chinquapin, *C. pumila* and the allied southern form or Alderleaf chestnut, *C. alnifolia*, both of which have very good, although very small, nuts. In some places the Japanese species is found to be the more resistant, in others the Chinese.

The late Dr. van Fleet of the U.S. Department of Agriculture devoted much attention to this subject and developed a number of hybrids which not only promise greater resistance to the disease but produce good nuts at an unusually early age, frequently at two to three years. At Glendale, Maryland, he had over two thousand hybrids and seedlings under observation. The latest results indicate that seedlings of the hairy Chinese chestnut (*C. mollissima*) offer the most promise so far as blight resistance, vigour, crop yield and quality are concerned. The Japanese nut is large but of poor quality, the Chinese smaller but of much better flavour, and the Chinquapin, although so small, is an excellent little nut, usually eaten out of hand. Dr. Morris has also developed two or three hybrids between the two American species, *dentata* and *pumila*, in which the Chinquapin characteristics are largely dominant and which are both decidedly resistant and of good quality nut. Luther Burbank, in the west, has also originated some extremely early bearing types by crossing and re-crossing Asiatic, European and American species and selecting for precocity in bearing and quality, but there the question of chestnut blight has not yet arisen. Where this is the case the native American chestnut, which is of very sweet flavour, bears good crops. The accompanying illustrations indicate generally

that the American nuts are in quite a different class to the fine large European varieties of *C. sativa*.

It may be of interest to compare the food values of some of the nuts to which reference has been made and the chief constituents given below are taken from Jaffa's table.*

	Water	*Protein.*	*Fat.*	*Carbohydrates.*	*Ash.*	*Calories.*
	%	%	%	%	%	
Filbert ..	5.4	16.5	64.0	11.7	2.4	3100
Walnut ..	3.4	18.2	60.7	16.0	1.7	3075
Butternut ..	4.5	27.9	61.2	3.4	3.0	3370
Chestnut (dry)	6.1	10.7	7.8	73.0	2.4	1840
Hickory ..	3.7	15.4	67.4	11.4	2.1	3345
Pecan ..	3.4	12.1	70.7	12.2	1.6	3300

In translating the experience of the States to this country, sight must not be lost of the widely differing climatic conditions, mainly in their favour The north eastern States have severe winters and occasionally suffer from extremely low temperatures, but the completely dormant winter period followed by high summer temperatures and a prolonged growing period give summer growths unequalled here. For the especially favoured western States, this may be illustrated by the following figures from a walnut grove in Oregon. Twenty acres of Franquette and Mayette grafted walnuts produced in their eighth growing season an average of thirty lbs. per tree, and the circumference below the first limb (the practice tends to head the tree low) measured twenty six inches. This is very far ahead in growth vigour of what can be found here but there are central, eastern and southern county areas where individual seedling walnut trees sufficiently indicate what may be expected from improved stock.

This country ranks high in its origination of fine varieties of the filbert and in its systematic though insufficiently widespread culture of this nut, but the same can hardly be said of the walnut. As starting material we almost certainly have native varieties really worth perpetuation and development may be hastened by the more general introduction of proved varieties from abroad. France, Italy, Spain, N. India, Chile, China, California and other countries afford a wide field for selection and trial.

The list of walnuts cultivated at Chiswick in the gardens of the Horticultural Society of London (Catalogue of Fruits, 1826), comprise some ten names of which half are French varieties.

* Nuts and Their Uses as Food." M. E. Jaffa, M.S. U.S. Dept. of Agriculture, 1908.

"*J. fraxinifolia*	Ash-leaved walnut.
J. regia	Common walnut.
	A coque dure.
	A coque tendre.
	Ducknut.
	Hâtif.
	Highflyer.
	Large fruited (double walnut, French walnut).
	Tardif: Noyer de St. Jean. J. r. serotina.
	Thin Shelled.
	Yorkshire."

This list is repeated unchanged in the second edition of 1831, and in the third, of 1842, the following notes are given:

"Common walnut. Among those raised from seed, varieties are to be found which bear and ripen better than some of the following larger sorts."

"Highflyer. Middle sized, fills well and ripens early."

"Large fruited. Shell tender, not so well filled as those of the other varieties."

"Yorkshire. Not double but of good size, fills and ripens well, shell moderately thin."

No walnuts are given in a supplement to the Catalogue published in 1853, and they are not included in the "List of the most desirable varieties of most kinds of fruits" published by the Royal Horticultural Society in 1917. The Highflyer is more fully described in the Trans. Hort. Soc. of London, IV., p. 517. "Grown in the town of Thetford, a variety which appears to have been originally confined to the neighbourhood of that place, and of Bury St. Edmunds, and which has of late become very scarce, from the great numbers of walnut trees felled during the late war for gunstocks. It is a long oval, with a shell so very thin that the slightest pressure of the fingers crushes it. The kernel is full, white, very tender and high flavoured. It is by far the best walnut grown; attention ought consequently to be paid to continue the kind by budding, on the plan recommended by the President in the Transactions of the Society,* for though varieties of walnuts sometimes, and perhaps frequently, reproduce themselves, no certain reliance can be placed on the quality of seedlings. The specimens exhibited were produced from trees growing in a small garden at the back of the house of Mr. Jackson, a grocer, in Thetford, and belonging to him."

* Vol. III., p. 133.

The "large fruited" walnut was probably of the Noix à bijou type and is possibly the "Bannut" which still gives excellent crops in Shropshire. This nut however, like the much better French Gourlande and the American Alpine Mammoth, Acme, Klondyke and other superior varieties of *J. r. maxima* are at their best only in the fresh milky condition, in which state, although never really well filled, they are excellent nuts. The Hâtif was possibly another name for the precocious *J. regia præparturiens* or Noix fertile; this comparatively dwarf walnut is highly commended in the "*Gardeners' Chronicle*," Series 3, Vol. 44, p. 409.

The walnut being so variable in practically all its chief characteristics—gowth vigour, time of blooming, leafage and maturing of crop,* precocity, productivity and the various features of the nut itself, affords as ample material upon which to work in the breeding and selection of improved varieties for our special climate and other conditions as any fruit tree. Comparison, *e.g.*, between the wholly wild nut indigenous in the lower Himalayas with the paper shell nuts of Chihli Province, China, would appear to indicate what selection alone (grafting the walnut is unknown in China) may achieve—unless indeed the numerous walnut species of Dode† are to be accepted. So far as breeding to a particular objective is concerned Burbank in California developed a variety in which the shell became so soft that it could readily be penetrated by the bills of birds‡ but this thinness of shell was a disadvantage and he found it desirable to breed the variety back to somewhat thicker shell covering. It was produced by his usual method of selective breeding and in particular selection was made for early and abundant bearing, whiteness and palatability of meat and absence of tannin. The perfected Santa Rosa may be depended upon to give more than twice as large a crop as the best specimens of Franquette.§ The San José Payne tree, earlier mentioned, which bears immense crops of nuts, was top-worked with this variety. Unfortunately it is very susceptible to walnut blight.

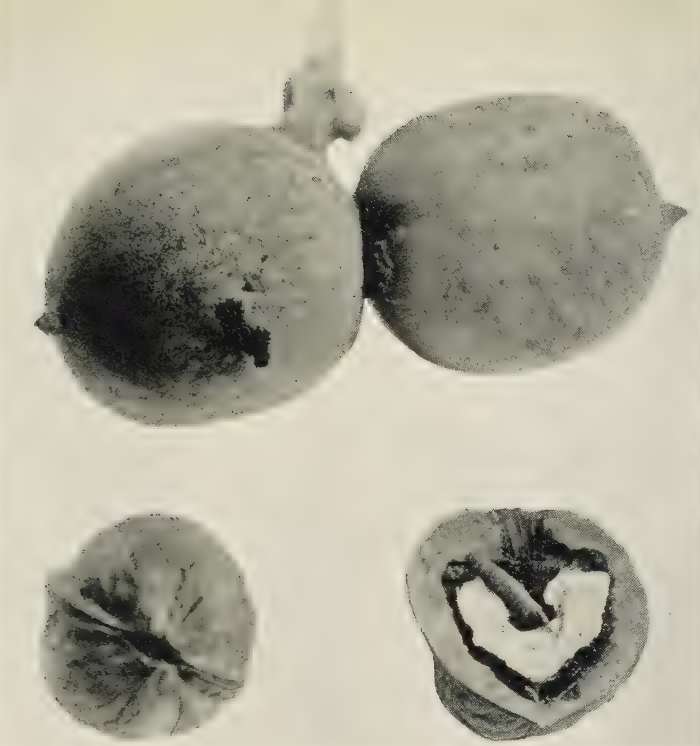
A combination of growth vigour and early crop bearing in the tree, coupled with regular yield of good sized, well-filled, non-astringent, moderately thin shelled nuts, is within the range of practical achievement. Chance seedlings in California have given rise to a large number of now standard varieties and as

* French varieties vary between two and three weeks in the ripening of their nuts, and some four to six weeks in the time they bloom, and there is similarly at least eight weeks difference between that of the "Soft shell" seedling varieties in California and of the introduced French nuts.

† Contributions à l'étude du genre Juglans, L.-A. Dode. Bull. Soc. Dendr. de France, Nov. 1906, Feb. and August, 1909.

‡ The French have also their "Noix à mésange."

§ Luther Burbank: His methods and discoveries. Vol. XI., p. 36.



CODLIN MOTH LARVA ATTACK ON IMMATURE NUT.
DUSTING TEST FOR CONTROL OF WALNUT APHIS.

IX

EFFECT OF STOCK ON GROWTH VIGOUR.

Four year old "Placentia" Walnut

on

J. regia stock.

J. californica stock.

Paradox stock (*J. californica* × *J. regia*).

practically the whole of our walnuts are seedlings it would be very surprising if, already, we do not have some varieties of high quality. The Highflyer is no longer known in Thetford but perhaps some " Bannut " seedling may be found to rival the California " Willson " (both descendants of the Bijou—*J. r. maxima*) in precocity and quality : a tree in Sussex is known to have the nut cluster form of the Noix à grappes (were this a desirable character to combine with others), and other special characteristics, if definitely identified, could contribute valuably to the improvement of walnut culture in this country.

The nature and crop of a locally famous walnut tree seldom become known outside a very limited area but with a focus for information on the subject generally its asexual propagation and perpetuation may become a possibility where none now exists. The Director of the East Malling Research Station (East Malling, Kent), Mr. R. G. Hatton, has kindly promised to record all useful information of this character which may be communicated to him from any part of the country and to afford access to such notes to any who may be interested. A permanent record of what may be known as to varieties of merit and crop yields over a period from individual, or groups of, trees of known location in this country would afford valuable material for future experimental work. That we can grow magnificent walnut trees throughout the British Isles is beyond question.* The late Mr. Elwes (" Trees of Great Britain and Ireland," Vol. II., page 261) says " I can find no records or measurements of walnuts abroad which show that it ever exceeds in warmer climates the size it attains here." This of course does not necessarily connote fruitfulness but excellent crops are gathered in many parts.†

There is one very considerable outlet for home produced walnuts which at present is, quite avoidably, largely supplied from abroad. This is the demand for green walnuts for pickling. The statement of a large user in this connection is illuminating and emphasizes the necessity for systematic co-operative effort to meet the reasonable requirements of the buyer. " We ourselves before the War were careful to buy our walnuts from Belgium or Holland if possible. In England walnut growing for pickles is very badly done, and they are always so busy with the soft fruits, or the harvest, that they neglect to collect the walnuts before they go woody, so we give them a wide berth."

* See, for example, " Old and Remarkable Walnut Trees in Scotland " (R. Hutchinson). Trans. Highland and Agricultural Soc. of Scotland. 4th Ser. Vol. XVI., p. 196 (1884).

† " On one of the farms that last year won the King's Cup for root cultivation in East Berks., there are forty-one large walnut trees, the crops on which are heavier than have been the case for over a quarter of a century. On farms such as this, the buyers having to gather them, and in years gone by over £100 has been obtained for the yield from these trees." (*Gardeners' Chronicle*, Ser. III., Vol. 44, p. 112.) At Beddington Park, Surrey, fifty walnut trees were formerly let at £30 to £50 annually according to crop. (Trans. Highland and Agricultural Society of Scotland. First Ser. Vol. V., p. 327.)

With the selection of varieties especially suitable for the particular purpose in view and in the absence of necessity for favourable conditions to ensure *ripening* of the nuts (a factor of considerable importance in our climate, and especially in the northern counties) it is certain much more of this field could be secured by our own growers.

Systematic experimentation is essential before it can be determined with certainty what are the best varieties generally, or for a particular area. In this country, where no other walnut is grown to any extent, it will probably be found that it may best be grafted on its own stock but there are undoubtedly very wide variations in the growth vigour of different " races " of *J. regia*—some having several times that of the normal and approximating closely to the most vigorous of the proportion of seedlings of the *Royal* hybrid walnut which reproduce this parental characteristic. The F2 generation of this cross, *J. californica* × *J. nigra,* is known in a number of cases at least, to give a percentage of seedlings equal in growth vigour to that of their parents : this appears to be an exception to the general rule in relation to second generation hybrids. Crosses between such vigorous *regia* types and, e.g. *J. nigra* or *J. cathayensis, cordiformis* or *mandshurica* offer interesting possibilities from a stock or a timber point of view.

Nothing strikes one more forcibly when travelling in this country than the charm and yet at the same time the average futility of the hedgerow tree. Even seedling walnuts in many cases would give the old Greek ideal of combination of beauty and utility and afford a chance at least in favourable years of a crop that would pay a substantial proportion of an acre's rent and, in the end, higher value as timber than almost any other. Grafted over to good varieties they certainly could do so and the grafting of cut back stems or branches of six inches or more in diameter is a commonplace in the States.

While in the Isère Valley (Grenoble district), one of the famous French walnut growing centres, and in the Department of Dordogne, there are many walnut plantations of small size in orchard form, very much the larger proportion of the French crop* is obtained (as is the case also over large parts of Italy) from trees which are scattered throughout the vineyards and wheatfields and along the borders. Under these conditions where two crops are under consideration, the trees are headed fairly high. The same conditions hold good in Lot and Corrèze in the south west—the crop chiefly being derived from roadside, fence and isolated trees in the cultivated field ; and the yield of a good tree will average two to four hundred lbs. This practice might well be emulated here in many places to advantage.

* The average annual French crop for the decennium ending 1913 was 59,503 metric tons with a value of 24,312,010 francs.

The bibliography relating to nut bearing trees of the species touched upon is already fairly extensive ; notes thereon will be forwarded with pleasure by the writer to anyone interested. In addition to the literature cited he is much indebted for many facts to correspondents in the States and to the publications of some of the nut Associations, and also to Dr. W. C. Deming of the N.N.G.A., to the University of California and to the California Walnut Growers' Association for material for some of the illustrations.

THE CONTROL OF THE APPLE BLOSSOM WEEVIL.

(*Anthonomus pomorum* L., Curt.)

By A. M. MASSEE, F.E.S.
East Malling Research Station.

As far back as 1920 the damage done by the Apple Blossom Weevil upon the young trees, set apart for the Apple-pruning experiments, became sufficiently widespread to endanger the general results of these trials. Despite the fact that East Malling had at that time the assistance of no entomologist, possible methods of controlling the pest in the field were initiated. It was decided to test certain more or less commonly recommended methods of control, and to analyse, as far as time would permit, the movements of the insect on the trees. The original programme was drawn up by Mr. R. G. Hatton, who was assisted in the execution by Miss K. P. Worsley. Such data as were collected during the years 1921 and 1922 were handed over to the writer of this present account, who became associated with this work in 1922, and took over the entire charge of it from 1923 onwards. At the beginning of 1921, a series of experiments were started on a plantation of seven-year-old bush Apple trees, used as a Pruning plot. For convenience, the various methods of control tested may be dealt with under the following headings :

(1) The value of hens, as being greedy devourers of many insects, including caterpillars, and some beetles.

(2) The jarring of the trees to dislodge the insects and the subsequent trapping of them on their return by grease-banding the trees.

(3) The use of Lime-wash in Spring, just before the blossom opens, or the application of an arsenical spray at the same period. The former wash was claimed to smother or impede the weevil, the latter to poison them direct whilst they are preparing a cavity for the reception of their eggs.

(4) The possibilities of various methods of trapping the weevil, such as banding.

(1) The Use of Hens.

Poultry enthusiasts often claimed that hens, running about in plantations, were a valuable asset in the control of the Apple Blossom Weevil. Moreover, Theobald[1] presented some evidence in support of this claim. After an

examination of the crop and gizzard of poultry he had on two occasions found the remains of weevil, principally *Otiorrhynchus picipes*, F., but also *Anthonomus pomorum*, L., Curtis. An experiment was therefore started, to find out if this method of control could be relied upon to reduce the pest under plantation conditions. A series of thirty-two Lane's Prince Albert bush apple trees was selected. This plot was divided into two equal parts. One half was entirely enclosed by wire netting, to confine the hens, yet to enable them to run about at will. The other half of the plot was used as the " control " or untreated plot. The hens used were twelve White Leghorn pullets. It should be mentioned here that the experiments commenced in the Spring when the weevils were plentiful on the trees. All trees, including those on the " control " half were grease-banded, the band being placed as high up on trunk as possible. The bands were thus out of reach of the poultry, and it was hoped that if the weevil proceeded from the ground by way of the trunk to the branches, these bands might give some measure of the numbers going up by this method on both plots. Finally, in order to dislodge the weevils from the branches, and give the poultry a chance of attacking them, the trees on both plots were severely shaken. This operation was carried out repeatedly on all trees. The grease-bands were left on the trees until September. The number of insects caught on the bands may be summarised as follows :—

	Apple Blossom Weevil.	*Leaf Eating Weevil.*	*Caterpillars.*
Plot with hens	13	39	11
Plot without hens	29	2,591	27

It will be seen that the number of Apple Blossom Weevils caught on the bands was very small ; in fact, the number does not suggest that grease-banding is of much economic importance in the control of this pest. This fact is further emphasised in a later experiment. In the Spring, following the penning of the poultry, the number of capped blossoms per tree, on the two plots, was counted. Whilst sixteen per cent. of the blossom on the trees under which hens had had free run was " capped," ten per cent. of the blossom on the " control " trees was " capped."

The pullets were generally sparingly fed and on several occasions considerable quantities of Apple Blossom Weevils, collected off the jarred trees in the plot, were given to them as food ; with a single exception, they did not take readily to these weevils as food, but after one or two pecks they ignored them, and went on scratching for other animal life in the soil. On the other hand, evidence is available to show that the same pullets acted as a very effective

control for another species of weevil, i.e., the Leaf-Eating Weevil (*Phyllobius oblongus*, Linn.). The figures already quoted lead irresistibly to this conclusion. As Theobald[1] has pointed out, poultry evidently have marked preferences and cannot be relied upon indiscriminately to control every species of weevil. On the other hand, growers might do well to remember that there is evidence that poultry help to control at least two species, the Leaf-Eating Weevil *Phyllobius oblongus*, Linn.) and, according to Theobald[1], the Raspberry Weevil *Otiorrhynchus picipes*, F.) which does so much harm to "the buds and grafts of Apple and Pear."

2. The Jarring and Grease-Banding of the Trees.

There is apparently a common belief that these weevils, especially the females, rarely if ever use their wings. As recently as 1920, P. J. Fryer[2] states, "The females are winged, but usually prefer to crawl up the trees." It was agreed that if this assumption was true, the weevils should be trapped on their way up the trunk by effective grease bands. Though as far back as 1909 Theobald[3] stated that "There does not seem sufficient evidence, however, to justify grease-banding for this pest," it was decided to try and collect some definite evidence upon the point. Some trees were banded on April 1st and 2nd ; These trees were then jarred, or shaken severely in the hope of dislodging the weevils in order to catch them on their return journey to the branches. Other trees in the same series were merely banded without being jarred, and a third series were left unbanded. A negligible quantity of Apple Blossom Weevil were actually caught on any of the bands, and an examination of the "capped" blossoms on the three series of trees in the subsequent Spring gave no result in favour of the banding, as the following figures show :—

Lane's Prince Albert and Gladstone Apples.

Jarred and banded	8 trees.	12.5 per cent. "capped" blossom.
Banded (only)	8 trees.	11 per cent. "capped" blossom.
Untouched controls	4 trees.	12 per cent. "capped" blossom.

It has been noticed that the mere jarring of a tree, to dislodge the weevils, is of little value ; as a matter of fact, it has been found that a severe shaking is necessary in order to make the weevils fall. It appears that it is a general thing for this particular species to make a hole right through a leaf with its rostrum, then should it desire to keep on the leaf, it is able to do so by placing its rostrum through the hole in the leaf, thus enabling it to get a firm hold. In fact, they may commonly be seen attached to the leaf by this method.

3. Lime Washing and Arsenical Sprays.

Between March 24th and 30th, 1921, the whole of the Apple pruning plot at East Malling was sprayed with a Lime wash. The lime was put on at the rate of 112 lbs. quicklime to the 100 gallons of water. The lime was slaked slowly on the headland, and applied with its natural heat thickly before blossoming. No weevils were observed on the trees at the time of spraying, though it was afterwards proved that they must have been present in quantity. Careful observations were made upon the trees following the application of the lime. Many of the weevils were actually observed to be laying their eggs in the normal manner, others were shaken in quantity from the trees and were closely examined in the laboratory. "Their wing cases were often tightly sealed, their legs showed balls of lime on the joints, . . . such weevils thoroughly coated in lime, were still fully active and able to perform their normal duties a good three weeks or a month after they had received the dressing."[4]

Lime-coated weevils were seen as late as the end of June, over three months after the application of the lime. There was no evidence of death caused by lime-spraying, though the spraying had been exceptionally well done. In a test of sprays, under laboratory conditions, Miles[5] found the killing efficiency of Lime Wash, 43 per cent. as against 100 per cent. where Paraffin Emulsion was used, but apparently these results were not sufficiently promising to extend the application of Lime Wash to a field trial. It can only be said that, under the conditions at East Malling, where the trees are young and without much loose bark, Lime Wash as a control for Apple Blossom Weevil proved anything but effective. This does not mean that Lime Washing may not be a commercial proposition as a general late dormant cleansing wash where trees are old, neglected or abounding in crevices suitable for hibernation.

On April 13th an Arsenate of Lead Wash was applied to certain apple trees which had already received the Lime Wash. The object was to spray the trusses with a poison, just before the blossom opened, to test whether it was possible to poison the weevils, whilst they were eating their way into the unopened flowers, previous to oviposition. White sheets were placed under the trees before spraying, and were left on the ground for forty-eight hours, to determine the number of weevils which dropped from the trees. Observations showed that weevils did not drop on to the cloths in any numbers, but that they remained alive on the trees. The percentage of "capped" blossoms on these sprayed trees did not differ from that upon a similar number of "control" trees. On the other hand, the writer of this report has made close observations upon the habits of the Apple Blossom Weevil, and is quite satisfied that these weevils do feed upon the epidermal surfaces of apple leaves to a considerable extent

both before and after oviposition. It is therefore at present not quite clear why an efficient application of Lead Arsenate fails to afford a considerable measure of control.

4. Trapping Methods: Sacking Bands used as a Means of Collecting Weevils when they go into Hibernation.

Trapping, as a method of controlling various weevils, has been recommended from time to time, although the particular method chiefly investigated at East Malling does not appear to have been commonly advocated in this country. Lees[6], in 1920, mentioned that trapping might "prove the easiest way on a commercial scale," and referred to this method of control being used in the Tyrol. Investigations on these lines do not seem to have been seriously followed up, and our attention to the real possibilities herein was drawn to the matter in 1920 by an accident. In July of that year it happened that the old sacking bands put round the stems of some of our apple trees, to prevent the rubbing of the stakes, were being removed, when Mr. C. A. Duffield, of the Entomological Department of the S.E.A. College, Wye, was visiting us. He started examining the bands to see what insect life they contained and it was found that a large number of Apple Blossom Weevil was present. This suggested the idea of placing strips of old sacking round Apple trees for the purpose of catching weevils when they seek hibernation. A preliminary experiment was commenced, to determine the most suitable time for putting on and taking off the bands. This investigation to shed light upon the habits of the weevil was begun in May, 1921, and was continued up to December, 1922. A plot of sixty-four bush Apple trees, Allington Pippin and Worcester Pearmain, was chosen on account of the large numbers of "capped" blossoms that had been noticed in the previous season. These trees were all banded at approximately fifteen inches from ground level. Every tree was examined weekly, the weevils contained were removed and counted, and these bands were then replaced. So that a complete record of the hibernating weevils might be obtained, white sheets were placed round the base of the trees before the removal of each band, in order that any weevils dropping to the ground might be noted. It was encouraging from a practical point of view, to find that few weevils actually dropped on the sheets, and that the great majority stuck to the bands, though a few remained on the trunks as is mentioned later.

The examination of the bands was continued for eighty-two consecutive weeks in order to get the annual cycle.[8] It is interesting to note that approximately fifty per cent. of the weevils caught, a total of 1,099, was found on each variety of apple, an aspect of the question which will be referred to again later. The following figures give the results :—

TABLE I.

NUMBER OF WEEVILS COLLECTED IN BANDS EACH MONTH FROM MAY, 1921—APRIL, 1922.

		No. of Weevils. in 64 Bands.	*Monthly % of Total Trapped.*
1921	May	136	12.3
1921	June	229	20.8
1921	July	233	21.2
1921	August	114	10.3
1921	September	49	4.4
1921	October	105	9.5
1921	November	57	5.1
1921	December	19	1.7
1922	January	21	1.9
1922	February	35	3.1
1922	March	63	5.7
1922	April	38	3.4

TABLE II.

NUMBER OF WEEVILS COLLECTED IN BANDS EACH MONTH FROM MAY, 1922—DECEMBER, 1922.

		No. of Weevils in 64 Bands.	*Monthly % of Total Trapped.*
1922	May	136	5.3
1922	June	943	37.0
1922	July	1,090	42.7
1922	August	130	5.0
1922	September	68	2.6
1922	October	110	4.3
1922	November	63	2.4
1922	December, 1st wk.	8	.3

It will be noticed that in both seasons the greatest number of weevils were taken in May, June, July, August, and October. These preliminary experiments were repeated between May, 1923, and April, 1924, but closer observations and fuller records were made. A plot of James Grieve Apple trees was this time selected. The trees used were a year younger than those used the previous season, although they were all on the same pruning plot. As before, all trees were banded with old sacking, at about fifteen inches above ground level. This banding began during the last week in April. Observations upon the bands for the collection of weevil were carried out weekly for a complete year. The object was, as already stated, to find out when the weevils were coming into

the bands, and so check the previous year's figures. However, in this experiment the weevils caught weekly were not destroyed, as in the previous case, but were put aside in order to study the development of the ovaries, and afford material for making certain observations on the life history of the weevil. These points will be dealt with later. The following figures summarise the results of this third year's analysis and should be compared with Tables I, and II.

TABLE III.

NUMBER OF WEEVILS COLLECTED IN BANDS EACH MONTH FROM MAY, 1923—APRIL, 1924.

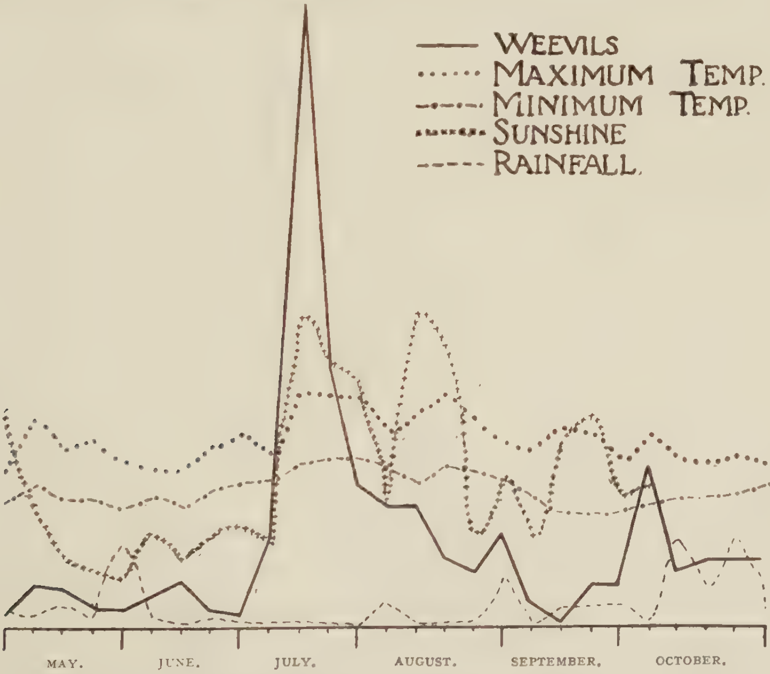
		No. of Weevils in 64 Bands.	*Monthly % of total trapped.*
1923	May	461	10.0
1923	June	170	3.7
1923	July	1,151	25.3
1923	August	838	18.3
1923	September	395	8.6
1923	October	833	18.2
1923	November	360	7.8
1923	December	59	1.3
1924	January	54	1.1
1924	February	33	.7
1924	March	103	2.2
1924	April	107	2.3

The curves (see graph No. XI), for the three years emphasise strikingly the fact that June and July are consistently the months when the greatest number of weevils enter the bands, and that the months after October are, comparatively speaking, 'rest' months. Considerable movement, this time out of the bands, begins again about the beginning of March.

The evidence seems to show that these movements are definitely dictated by a more or less fixed life cycle, possibly varying slightly with the time of blossoming. It appears that about one month after egg-laying, there is a general impulse to seek rest. This rest seems very general for the period of three to six weeks, after which more moving about is again obvious until October, when there is a marked influx of weevils once more.

In order to see how far these movements coincided with weather conditions, a graph has been plotted for six months showing the temperature, sunshine and rainfall curves in comparison with the curve representing the impulse to "hibernation" of the weevil. It will be noted that weather and temperature conditions bear no apparently close relationship to this movement. Some consideration has also been given to other possible external factors which might influence

XI.—GRAPHS SHOWING VARIATION IN "HIBERNATION" IMPULSE OVER A PERIOD OF THREE YEARS.



XII.—GRAPHS SHOWING VARIATION IN "HIBERNATION" IMPULSE AND ACCOMPANYING WEATHER CONDITIONS.

the movements of the weevil. For instance, it was possible that they might be more attracted to the trees full of blossom rather than to those markedly less so. The pruning plots upon which these observations have been carried out were very suitable for such an analysis, since the rows of "unpruned" and "regulated" trees generally showed a notable increase in blossom, against both the long and short spurred rows, which were also "leader-tipped." The figures for the year 1923 gave the following indications :—

16 unpruned trees	1,286 weevil caught.
15 Regulated trees	1,207 weevil caught.
16 Tipped and Long Spurred Trees	1,082 weevil caught.
16 Tipped and Short Spurred Trees	995 weevil caught.

A distinctly more marked result came from a study of the location of the trees. At one end of the plot is a poplar hedge, the bottom of which might be expected to afford cosy winter quarters, with fallen leaves, rough grass and loose bark. The other end of the plot abutts on a much used roadway, where no such facilities exist. The following are the figures :

31 trees nearest road	2,036 weevil caught.
32 trees nearest hedge	2,534 weevil caught.

The question of varietal susceptibility was also considered. In 1922, Worsley banded thirteen of the varieties represented on the pruning plot. In practically all cases thirty-two trees of each variety on each stock were banded, though in occasional instances bands fell off individual trees before the completion of the experiment. The following are the figures, when all the bands were taken off at the same time in December :—

TABLE IV.

Variety.	*Years old.*	*Weevils caught.*
Annie Elizabeth	6 years	134
Bismark		178
Early Victoria on "Par." ..		214
Rival		236
Gladstone on "Par."		283
James Grieve on "Par." ..		287
Norfolk Beauty	8 years	228
Gladstone on "Crab"		275
Cox's Orange Pippin		302
James Grieve on "Crab" ..		298
Lord Derby		313
Early Victoria on "Crab" ..		339
Worcester Pearmain		420
Grenadier on "Par."		436
Grenadier on Free Stock ..	9 years	481
Beauty of Bath		472
Lane's Prince Albert		457

Before banding could be recommended as an economic method of controlling Apple Blossom Weevil, it was essential to discover how far the trapped insects actually represented the generation capable of carrying on the race in the following season, and how far they were merely "spent females" which had once and for all done their work, and hibernated until overtaken by natural death, as has been suggested. In order to settle this point, all weevils that were found in the bands in June and July, the principal months for immigration, were kept in captivity and under observation. In the following Spring, they were put on to young Apple trees in pots In all cases, these weevils lived, and after copulation, the females deposited their eggs in the flower trusses. These observations were checked for two seasons. Under certain conditions adult female weevils survived to the second blossoming season and actually laid eggs in two consecutive years. In recent work, Speyer[7] found that *Anthonomus pomorum*, L., Curtis, may have two oviposition periods, and these results have been confirmed by further experiments. Under conditions at Malling, it was found that the trapped weevils showed an almost equal proportion of males and females, though it had been generally considered that the former were more numerous, Although the actual number of weevils trapped on sixty-four trees does not appear to be very large, the amount of damage they would have done upon these young trees can be approximately gauged when it is realised that each female is capable of destroying up to sixty blossoms. According to Speyer[7] it is possible for one female to lay as many as 144 eggs, the egg-laying period being extended over two years. As the trees grow larger, if the weevil population does not increase in proportion, the damage tends to become more insignificant. Despite our trapping, the weevil population, as estimated by those caught, has steadily increased each year, and yet the damage done is undoubtedly less serious than it was in 1920 and 1921. The fact that there is some migration from tree to tree and possibly even from one plantation to another would be sufficient to account for this actual increase, since our experiments have in the main been confined to the regular banding of only sixty-three trees in a three and a half acre plantation. If the trapping had been as systematic as it appears promising, there is reason to suppose that very large catches of weevil would have been recorded.

That banding would be worth while under conditions such as ours was so evident that certain details were elaborated from the practical point of view, in order to guide the grower as to the seasons for application and removal of his bands, and their actual manipulation, etc. With regard to the best time for application, our graphs have shown that June and July are constantly the most vital months and, that therefore the bands should be applied if possible by the end of May.

The question then arose as to whether the bands should be removed immediately after this influx, say in August, in order to destroy this biggest number,

or whether it would be safe to leave them on until well into the winter, secure in the knowledge that the weevil that sought shelter in June and July would not emigrate again in quantity. Since figures constantly showed that weevils in fair quantity continued to come into the band until the end of November, it would naturally be desirable to leave these bands on if no loss of previous captures were entailed thereby. To determine what was actually happening, a series of trees were banded, and instead of all the bands being removed weekly for examination, as in the former series, only a certain number were removed at fortnightly intervals. For instance, the first batch of eight bands were examined after they had been on the trees two weeks only, the second batch after they had remained four weeks, and so on, until the last batch was removed after twenty-six weeks duration on the trees without disturbance. The following table (No. V.) shows the steady increase right up to the time when the weevil are observed to emerge, towards the end of February.

Table No. V.

Illustrating the Steady Monthly Increase of Immigrating Weevil up to February.

All bands put on trees 10th Sept., 1923.	Number of Weevil in bands.
Bands removed after 2 weeks	24
,, ,, 4 ,,	59
,, ,, 6 ,,	120
,, ,, 8 ,,	158
,, ,, 10 ,,	158
,, ,, 12 ,,	172
,, ,, 14 ,,	181
,, ,, 16 ,,	207
,, ,, 18 ,,	208
,, ,, 20 ,,	229
,, ,, 22 ,,	248
,, ,, 24 ,,	205
,, ,, 26 ,,	189

Even the periods of severe weather during the winter of 1923-24 did not disturb the weevils which remained in the bands during frost and snow. Once, then, the weevils get into hibernation they do not appear to move about to any considerable extent, though some, as our figures indicate, either must change their quarters, or seek hibernation very late in the season. On one plot of trees where the bands were removed weekly, in order that the number of weevils might be recorded, but not disturbed, the number of weevils actually remained unaltered during the whole twenty-six weeks. It is evident, therefore, that it is quite safe

to leave the bands on the trees until late in the year, and the best time for their removal is during the month of December or January.

In order to see whether it would be possible to make the sacking traps more attractive by different manipulation such as folding, etc., careful records were taken over two seasons of the position of the weevils in the sacking traps. Whilst the first season gave the most decided results in favour of the fold, the second season reversed the position.

	1922-3	1923-4
% of weevil caught in fold	68	27
% of weevil caught between sacking and stem	32	53
% of weevil remaining on stem	—	20

The variation may be a seasonal one, but in any case the double thickness of banding must afford more protection in cold and wet seasons, and the more weevils that can be removed in the band, the fewer will there be left on the bark or liable to be shaken off on the ground. It is interesting to note that with normal rough handling of the bands, eighty per cent. of the weevils at least would have been removed undisturbed.

With regard to the position of the weevils above and below the "tie," certain data are available. They were distributed in almost exactly equal numbers (forty-seven per cent. above tie, fifty-three per cent. below tie) in the sacking above and below the string tie. The weevils therefore appear to enter the bands both from above and below; this should dispose of the growers' theory that it is necessary to tie the bands as near the top as possible, since all the weevil crawl up from the ground into the sacking from below.

METHODS OF MANIPULATING THE BANDS.

Discarded bags which had contained meal and artificials and other waste sacking was collected and cut into long strips. The width of each strip was about six inches, and each strip was cut in length so that it would be at least twice that of the circumference of the tree, in order that the band could be of double thickness by folding across the middle. Many other methods of folding bands have been tried, for example, bands folded lengthwise (or doubled over) did not attract many weevils, neither did single bands placed round the tree without any fold at all. The double thickness of sacking which allowed free entrance both above and below the tie, gave the best results over a period of three years.

POSITION OF BANDS ON TREES.

The best position of the band on the tree was also investigated, and it was found that this detail might make the whole difference between success and failure. In order to ascertain if the position did materially affect the number of weevils going into the band for the winter, a series of trees were banded at different heights. One set of trees which were originally headed back at two feet had bands placed so that the base was about twelve inches above ground

level. The other series had the bands at the base of the trunk so that they just touched the ground. The bands were put on in September, 1921, and left till the end of December. Whilst 106 weevils were collected from the bands placed at twelve inches from the ground, only five were taken from bands on the ground level. This work was repeated the following year, and a similar result was obtained on a larger plot of trees. Where the bands were placed as near the fork of the branches as possible, 625 weevils were captured as against 269 which were taken from those close to the ground. It seems probable that the difference in effectiveness is due to the fact that whilst the bands at ground level remain sodden all winter, those in a higher position remain comparatively dry. It should be pointed out that trees grown on a very short leg, in many cases only a six inch leg, would be much more difficult to band successfully.

It might be mentioned here that apparently the kind of sacking used for catching the weevils is not of importance, for example, weevils seemed to be attracted to the old uncleaned guano bags, to the same extent as to old hop-pocketing, or even new sacking.

At the request of Mr. Miles, of Long Ashton, the use of paper bands, as compared with sacking, was tested in 1922. These bands were first applied on May 5th, and were not ultimately removed until December 10th, though they were were examined as frequently as the sacking bands with which they were being compared under our conditions. At the end of the period a total of only eighteen weevil had been recorded in the paper bands, as compared with a total of one hundred and thirty-six in a similar number of sacking bands. Under our particular condition's these results did not appear to call for further trial.

On our small scale, we have usually burnt our sacking bands in order to destroy the weevil, but where such a measure is to be used on a considerable scale, economy in sacking might be necessary. If the sacking is good enough to save for a second season, it can, immediately after removal from the tree, be thrown into a tub of water with a few stones to sink it and prevent it floating. A film of paraffin can then be poured on the surface of the water, and this will ensure the destruction of the weevils. In due course (after it has been ascertained that all the weevils are dead), the tub can be carefully emptied, the strips of sacking dried, and used again the following May.

Incidentally these sacking bands trap various other insects both in Summer and Winter. Earwigs are very common during the Summer months, and when the weather is very warm great quantities of green-fly (*Anuraphis roseus*, Baker) have been found to shelter in the bands. The larvæ of Syrphid flies, which devour the green-fly, follow. In the Spring, the Clay Coloured Weevil (*Otiorrhynchus picipes*, F.) is commonly found in the bands in considerable numbers, and this suggests a possible method of controlling this pest when it is ravaging newly-grafted stocks. Close examination also showed that another

species of weevil, possibly often mistaken for the Apple Blossom Weevil (*Anthonomus pomorum*, L., Curtis) are not uncommonly to be found in the bands. Some of the small specimens found may prove to be a closely allied species, well known on the Continent as *Anthonomus humeralis*, Panz=*incurvus*, Panz). This species was first recorded in this country in 1869 by Stephens[9], but seems to have been overlooked since then. Other closely allied species of *Anthonomi* are to be found in the bands; *Anthonomus cinctus* and *Anthonomus rubi*, Herbst, are of frequent occurrence. Various species of larvæ are also common in the bands, and some actually pupate in the fold of the sacking.

Finally, a word may be said as to the amount of parasitism that takes place among the weevils during the larval stage. In order to shed some light upon this point 5,000 "capped" blossoms were collected and allowed to develop normally, whilst they were kept under observation. Over ninety per cent. of these blossoms produced weevils. The rest failed to mature. Only five parasites were observed, belonging to an hymenopterous parasite of the family Ichneumonidæ (genus, *Pimpla*). So that under our conditions at least the "parasite" did not appear to be a very promising corrective.

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THE PHYSICS OF SPRAY LIQUIDS.

I.—THE PROPERTIES OF WETTING AND SPREADING.

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INTRODUCTION.

It is now a well-known fact that the physical properties of spray liquids used in horticulture and agriculture are quite as important as the toxicity of the substance employed in the making of the spray. To be efficient, the spray should be quickly toxic to the organism it is destined to destroy; and, moreover, it should be capable of wetting and spreading over the surface on which the organism lives.

There is generally little difficulty in finding a cheap toxic substance for a spray; the failure of a spray is not usually due to lack of toxicity (which may often be varied at will by altering the percentage of toxic substance present), but rather to the absence of certain desired physical properties.

"Wetting power" and "spreading power" are usually regarded as synonymous terms, and hence such expressions as "to wet and spread over a surface" are common, implying that if a liquid wets a surface, it will also spread over that surface. That this is not the case can be shown by a simple experiment. Alcohol placed on a flat wax surface does not *spread* after it has covered a certain area; on the other hand the alcohol does not recede from that area on tilting the wax surface, i.e., the alcohol *wets* the wax. Thus, although the alcohol wets the wax, it shows no tendency to spread continuously over that surface.

It would be true to say, however, that a liquid, before it can spread over a surface, must wet that surface, wetting being merely a consequence of the reduction to zero of the angle of contact between the liquid and solid.

It is important, before attempting investigations of the mode of action of spray liquids, to formulate some quantitative measure of the "wetting" and "spreading" powers of pure liquids for a given solid surface.

Harkins and Feldman (1) have shown that the criterion of spreading or non-spreading of one liquid over the surface of another may be given in terms of a simple thermodynamically determined co-efficient, known as the "spreading co-efficient." They were unable, however, to give any results for the spreading of liquids on solid surfaces, because of the difficulty of preparing uncontaminated solid surfaces and the present impossibility of determining the surface tension of a solid.

Cooper and Nuttall (2), in a valuable paper on the theory of wetting, make use of the fact that a liquid will spread over a solid surface if

$$T_2 > T_1 + T_{1,2},$$

where T_1 = surface tension of liquid,

T_2 = surface tension of solid,

$T_{1,2}$ = interfacial tension of solid-liquid.

As T_2 and $T_{1,2}$ are indeterminable experimentally, it is impossible (as was the case with Harkins' and Feldman's co-efficient), to subject the equation to a practical test. From the equation, however, it is seen that reduction of T_1 *or* $T_{1,2}$ facilitates wetting ; hence their method of experiment resolved itself into a measurement of T_1, for different spray liquids by the Donnan drop-pipette, where the solid was replaced by a standard thick paraffin oil.

In the same investigation, they examined the question as to how far the weight of liquid adhering to a strip of solid not easily wetted by water, could act as a criterion of the wetting power of the liquid for that solid. It is natural to suppose that, on dipping the same solid surface into different liquids, differing amounts of the liquids would be retained by the surface, because of the varying surface tensions of the liquids and the varying interfacial tensions of the liquids and the solid. A low surface tension and interfacial tension, would cause the surface to be wetted completely on immersion ; on withdrawal all excess liquid would run off, leaving a continuous film characteristic of that liquid for the given solid surface. The effect of adsorption would involve a resistance to draining, and hence a larger amount of liquid retained as a film.

It is obvious therefore, that before this method of experiment could be employed as a criterion of wetting power, it would be necessary to ensure perfect wetting of the solid surface in order to secure a continuous film.

The method adopted by Cooper and Nuttall was to dip a piece of tubing, coated internally and externally with a thin layer of collodion (which they found to be a suitable substance), into a weighing bottle containing the liquid, and then to withdraw the tube. By weighing the bottle and contents before and after the experiment, the amount of liquid adhering to the tube was found. They used three liquids, namely, distilled water, 1 per cent. saponin solution, and a castor oil soap solution containing emulsified green oil. In the first case 0.0282 gm. and 0.0356 gm. were retained in two experiments ; in the second case 0.0764 gm. were retained, indicating adsorption or surface concentration ; in the third case 0.0520 gm. due to low surface and interfacial tensions.

In view of the great differences in wetting power which are known to exist in the three liquids examined, it was considered by the investigators that the differences in weight of retained liquid were too slight to act as a satisfactory criterion of differences of wetting power. In the opinion of the writer, however,

the observed differences are not unsubstantial when considered in relation to the actual weights of the liquid films retained in the three experiments. Moreover, this type of experiment is probably the most direct and natural way of attacking the problem of retention of liquids by solid surfaces, since it is reasonable to assume in the first place, that no retention of liquid is possible unless the liquid possess the power of wetting the solid, and secondly, that if a liquid is able to wet a surface, then the weight of the retained film of liquid will bear some relation to the wetting power, as conditioned by the surface tension of the liquid and the interfacial tension of the solid and liquid.

In view of the foregoing, it was decided to submit the principles embodied in the above method to a thorough test in an investigation of the effect of lowering the surface tension of a liquid on the amount retained by a solid surface.

SCOPE OF PRESENT INVESTIGATION OF WETTING POWER.

In the work to be described in this communication, the factor of interfacial tension between liquid and solid has been left out of account, since in the first place it is not possible to measure it experimentally, and in the second place, it is probable, as will be made clear in a later section, that too much importance has been attached to this factor to the exclusion of the surface tension of the liquid itself (3).

Varying mixtures of alcohol and water of known surface tension were used, although, of course, alcohol would never, on account of its prohibitive price, be used in practice. The advantages of using this liquid in this initial investigation were threefold: alcohol and water are miscible in all proportions; a smooth curve is obtained for the surface tensions of such mixtures (4); and, finally, little interference is to be feared from adsorption effects.

It was essential that the surface chosen for the wetting experiments should be clean and standardised in every respect. Two modes of experiment were possible: (i.) To use a surface which is not completely wetted by water and determine how reduction of surface tension influences the amount of liquid retained by the surface; or (ii.) to use a surface which is completely wetted by water and again determine how reduction of surface tension affects the amount of liquid retained.

A glass surface was chosen for the following reasons. It could easily be cut to standard size and could be cleaned without difficulty. Moreover, it could be employed in both types of experiment mentioned above and could be regarded, as will be shown later, as an approximation to a smooth leaf.

Preliminary experiments in obtaining a perfectly wetted glass surface were carried out with cover slips (2in. by 1in.). The latter were manipulated by means of clean forceps, in order to avoid contact with the hand. A coverslip

was immersed for a time in fresh chromic acid and then washed successively with running tap water, alcohol and ether, the usual procedure of obtaining a "chemically" clean dry glass surface being followed. It was presumed that the cover slip would now be wetted by water, since the angle of contact of water and "quite" clean glass is zero (5). On swilling the coverslip cleaned in this manner under the tap, however, and withdrawing, the water "rolled" away from the glass into adherent droplets. It was found that on stopping the process of cleaning after the chromic acid or the alcohol stages, and then swilling under the tap, a perfect film of water was obtained, which, in a perfectly still atmosphere, dried uniformly, and displayed Newtonian colours in the drying. It thus appeared that the effect of non-wetting was connected with the ether stage of cleaning. Accordingly the process of cleaning was repeated, using perfectly anhydrous and fat-free ether. Under these conditions, however, the glass was still not wetted by water, and it was thus apparent that this phenomenon was due not to impurities in the ether but to a change in the character of the glass surface brought about in some manner during the quick drying off of the ether.

It was further found that chemically clean dry glass could not be perfectly wetted by water, even after boiling in water, in alcohol, or in ether, and rubbing the glass under the boiling liquids with fat-free cotton wool held by forceps. Furthermore, when a coverslip covered with a continuous film of water (i.e., a perfectly clean coverslip) was dried by means of fat-free cotton wool, or by pressing between fat-free blotting paper to avoid deposition of atmospheric grease, the glass surface was no longer wetted by water.

On heating a cover slip in a bunsen flame, allowing to cool partially, and plunging in water, perfect wetting was obtained. Metals like lead, tin, aluminium, iron, copper and also mica showed this phenomenon.

It is evident then that when a glass surface dries, the process is accompanied by the development of a contact angle which results in non-wetting or wetting of an imperfect kind, even though the glass surface be chemically clean. Bancroft (6) assumes non-wetting of a solid to be due to an adsorbed layer of air, for solids can adsorb gases to an appreciable extent. But concentrated sulphuric acid wets dry glass, and water wets the glass after swilling off the acid. Since concentrated sulphuric acid was found to possess a somewhat higher surface tension (approximately 76 dynes/cm.) than water (73 dynes/cm.), it follows that the wetting is due probably to a very low interfacial tension between acid and glass, assuming that the surface tension of the glass itself is not altered by the acid. This behaviour raises several interesting questions as to the manner in which the acid removes the adsorbed air, or alternatively, as to the way in which the low interfacial tension between acid and glass becomes operative through the film of adsorbed air. The fact that the glass surface is wetted perfectly by water after swilling off the acid appears to point to a reduction of the interfacial

tension between water and glass, and this also would be difficult of explanation on the " adsorbed air " theory.

Rayleigh (7) showed that when glass was heated in a smokeless flame, water could readily spread over it, even after the surface had been in contact with *pure* air for several days. On the other hand, however, if the glass were kept in contact with the *open* atmosphere for some time, it was no longer capable of being wetted. Rayleigh attributed the latter behaviour to the deposition of a thin film of grease, probably adsorbed. It is thus probable that heating the glass in a smokeless flame removes the grease film and enables the surface to be wetted. If, however, this explanation be valid, then it is difficult to understand why a glass surface is not capable of being wetted perfectly when a cover slip is immersed in boiling ether and, after allowing the ether to evaporate, plunged into water, the process of drying and plunging being completed in about a second. It is also difficult to reconcile with this theory the fact that a glass surface is not wetted perfectly after washing with hot soap solution, or even after drying perfectly wetted glass between fat-free blotting paper, a procedure which should preclude the deposition of grease films.

Apart from theoretical considerations, however, the important fact remains that a glass surface which has been in contact with air is not wetted by water, owing to development of a contact angle. According to the contact angle theory of wetting (8), it is necessary to reduce the contact angle to zero to produce wetting. Thus, if Θ be the angle of contact, then

$$\cos \Theta = \frac{S_1 - S_{1,2}}{S_2}$$

where S_1=surface tension of solid.

S_2=surface tension of liquid.

$S_{1,2}$=interfacial tension of liquid and solid.

For perfect wetting, Θ must be equal to zero and therefore

$$\frac{S_1 - S_{1,2}}{S_2} = \cos 0^\circ = 1$$

$$\text{i.e., } S_1 - S_{1,2} = S_2.$$

It follows that wetting will be possible when the difference between the surface tension of the solid and the tension of the liquid-solid interface is equal to, or greater than, the surface tension of the liquid. If, on the other hand, S_2 is greater than $(S_1 - S_{1,2})$ then cos Θ is less than unity and the contact angle lies between 0° and 90°. In such a case, wetting can only be made possible by increasing S_1, or decreasing S_2 or $S_{1,2}$.

Edser (8) has pointed out that the effect of diminishing the liquid-air tension (S_2) is of the greatest importance and is apt to be overlooked, while undue

stress is probably laid on the solid-liquid interfacial tension ($S_{1, 2}$). Both alcohol and soap solution are able to wet glass, and the former, wax. That this is not due to any increase in S_1 is shown by the fact that the surfaces are not wetted by water subsequently. In view of the large reduction of S_2 (from about 70 to 20 dynes/cm.), the wetting may be attributed to this, rather than to a decrease in $S_{1, 2}$.

In the experiments now to be described, chemically clean dry glass was taken as a solid whose surface was not wetted by water. For reasons given later, such a surface was regarded as approximating to that of a *smooth* leaf. In other experiments, glass was used which was perfectly wetted by the liquid under examination. The surfaces were prepared by washing first in fresh chromic acid solution, and then in water and finally preserving in the liquid to be investigated.

DETERMINATION OF SURFACE TENSIONS OF WATER, ALCOHOL, AND MIXTURES.

The surface tensions were determined by Searle's Torsion Balance, using the glass slide provided with the apparatus. As ordinarily used, the slide is cleaned and dried in the usual manner with chromic acid, water, alcohol and ether. It has already been shown, however, that this procedure involves the development of a contact angle, and the tension as thus determined cannot be accurate, as perfect wetting of the slide is not obtained. The surface tension at 15°C. of pure water was determined with a slide cleaned in this manner. A second slide was then cleaned in the same manner, placed in the clip of the apparatus, and the lower "measuring" edge of the slide allowed to dip into $\frac{1}{12}$-in. of fresh chromic acid solution for a few minutes. The chromic acid on the edge of the slide was then replaced by a film of pure water by allowing the edge to dip into successive quantities of pure water. The surface tension of pure water was then immediately determined without allowing the film on the edge to dry, the contact angle being then zero. The surface tension obtained in this manner was higher than the values obtained in the experiments where the slide was not treated, and it was thought that it might in this way be possible to devise a method for obtaining rough comparisons of surfaces on the basis of contact angle measurements.

The lower half of the slide was now coated with a thin, regular film of paraffin wax, and the surface tension of pure water determined, using the waxed surface. Indications of the existence of two values for the surface tension were obtained in this experiment. If the surface tension were determined immediately following contact of water and wax, then a low and somewhat variable value was obtained (approx. 32 dynes/cm.). If, however, the determination were carried

out after the wax and water had been thoroughly in contact from one to five minutes, then the value obtained was much higher, namely, 49.12 dynes/cm. Moreover, the latter value was not subject to much variation in several determinations.

During the determinations the vessel containing the water was kept in a thermostat at 15°C. The thickness of the waxed slide was measured carefully by means of a micrometer screw gauge, just as was that of the glass slide. The following results were obtained :

(i.) Slide chemically clean but dry 73.69 dynes/cm ($\pm$ 0.5).
(ii.) Slide perfectly wetted along edge 76.56 dynes/cm. ($\pm$ 0.1).
(iii.) Waxed slide :
 (*a*) Low value : 32 dynes/cm. (subject to variation.)
 (*b*) High value : 49.12 dynes/cm. (not subject to variation).

Assuming in the second case, where the continuous film exists along the edge, the angle of contact to be zero, and that the variation of surface tension is due to a difference in contact angle, it is possible to calculate approximately contact angles for the other cases. Thus the ratio of the apparent surface tension of water with a given surface to the true surface tension of water with a surface perfectly wetted by water (contact angle zero), can be taken as the cosine of the angle of contact of water with the unwetted surface. Thus in case (i.) :

$76.56 \cos \theta = 73.69$. $\theta = 15°45'$=angle of contact of clean dry glass and water.

Case (iii.) (*a*) $76.56 \cos \theta = 32$. $\theta = 65°18'$=first angle of contact of wax and water.

(*b*) $76.56 \cos \theta = 49.12$. $\theta = 50°5'$=second definite angle of contact of wax and water.

The contact angle of water and wax is known to be about 50°. Further, Bigelow and Hunter (9), by using the capillary tube method and discs of various substances at the meniscus of the column of water in the same tube, obtained different heights of the water column. Edser (10) has shown that the ratio of the heights (which is really the ratio of the surface tensions), when using a wax disc and a glass one, is the cosine of 50°.

Searle's torsion balance thus seems capable of indicating the contact angle of a surface for a liquid ; it also indicates two contact angles for a given surface with a liquid. This might be due to two things,(*a*) the "age" of the surface in contact with the liquid or (*b*), the "hysteresis" of contact angle first noticed by Sulman (11), which tends to show that "when a liquid reaches its final state of equilibrium by spreading over the dry surface of a solid, the contact angle is greater than when the liquid reaches its final state of equilibrium by receding from a previously wetted surface."

Searle's method possesses the advantage that slides of different solids can easily be prepared. Thus a " slide " was cut from a cherry-laurel leaf, and the surface tension of water actually in contact with the leaf surface was measured. Two contact angles were again noticed :

(*a*) Surface tension when leaf surface is freshly in contact with water$=$ 67.44 dynes/cm. Angle of contact$=28°12'$.

(*b*) Final surface tension$=$73.21 dynes/cm. Angle of contact$=17°0'$.

The results indicate that the " average " final contact angle of water with a cherry-laurel leaf surface is of the same order of magnitude as that for a clean dry glass slide (about 16°) ; hence the choice of glass to represent a smooth leaf in later experiments. The results also indicate that the initial angle of contact for a cherry-laurel leaf and water is about 30°. This leaf is a highly waxed leaf, and it is reasonable to suppose that any liquid which will wet it will also wet most leaves met with in horticulture. It should, however, be pointed out that a rather different problem is involved in the wetting of " hairy " leaves. This phase of the question will be dealt with in future investigations.

In view of the fact that wax, which possesses a contact angle with water of 50°, is wetted by an alcohol-water mixture of surface tension of about 25-30 dynes/cm., it is reasonable to expect that it should be possible to wet most leaves by means of liquids of even greater surface tension than 30 dynes/cm., since the angle of contact for such leaves will be much less than 50°. This was shown to be the case in laboratory tests.

Reduction of the surface tension of water to 30 dynes/cm. can easily and economically be effected for the purpose of spraying (e.g., by means of soap at 0.1 per cent. concentration). It thus seems fair to conclude that the surface-tension of the liquid used in spraying is a far more important factor in the wetting of leaves than the interfacial tension between leaf and spray-liquid.

Another factor to be taken into account in spraying is the existence of the two contact angles. The surface tension must at least be reduced so as to cope with the larger initial contact angle. It is obvious that if the surface tension of the spray liquid has been reduced merely to the extent required to cope with the final smaller contact angle (corresponding with the " steeping " of leaves in the liquid), then there will be the danger of the spray dripping from the leaves, by the combined action of gravity and force of spraying, and thus not remaining in contact with the leaf surface long enough for the effect of the smaller contact angle to become operative, the time for this being one to five minutes.

The question of the dripping of sprays from the leaves leads naturally to the investigation of the conditions requisite for the retention on them of the maximum amount of spray. With this object in view, the following series of experiments was carried out with glass surfaces.

RETENTION OF LIQUIDS BY SOLID SURFACES.

A chemically clean glass cover slip (2in. by 1in.) was placed in a weighing bottle provided with a specially ground outside top, so as to render it perfectly airtight. The bottle and cover slip were then heated in the water oven, cooled in a desiccator, and the whole weighed. After next immersing the cover slip in chromic acid solution and swilling successively in tap water and pure water, (a procedure which ensures perfect wetting of the glass surface), the slip was totally immersed long edge downwards in pure water, being held at one edge by specially bent forceps during the process. The slip was then carefully withdrawn, placed in the weighing bottle, and the amount of water retained was weighed.

The results obtained with the same slip in several experiments varied within fairly wide limits (0.0480 gm. to 0.0353 gm.) It was observed however, that when contact with the liquid surface was broken during the withdrawal of the slip, the lower edge of the latter had a " rim " of water attached to it. The volume of this attached " rim " was, even to the eye, very different in the several trials. Another disturbing factor arose from the observation that the rate of withdrawal of the slip appeared to determine the thickness of the retained film of water.

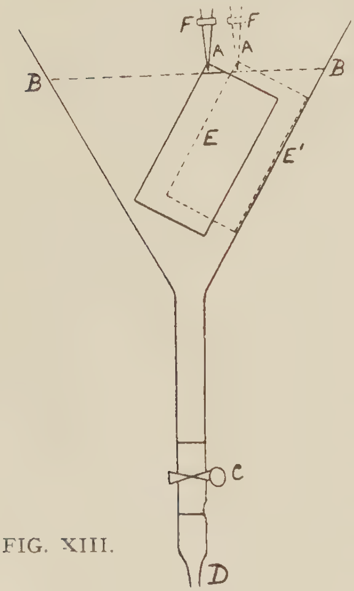

FIG. XIII.

It was thus apparent that in order to obtain uniform and comparable results it was necessary to ensure withdrawal of the slip at a constant rate in all experiments and further to avoid retention of " rims " of water on the lower edge. Several methods for ensuring constant rate of withdrawal of the slip were tried without success and it was finally resolved to modify the procedure so that the liquid itself was drawn off from the slip at a constant rate, the slip being kept stationary during the process. This was accomplished as follows, the general arrangement of the apparatus being shown in the accompanying diagram (XIII.).

The slip was held by forceps fixed in a clamp, the jaws of the forceps A being manipulated by a brass ring or collar F. The slip was placed with its long edge along the side of the funnel at E^1, so that in every experiment it occupied exactly the same position. It was then brought (by moving the clamp-stand), to the central position as at E. Water was poured into the funnel to the level B. The clip C was opened, and the water ran off through D. The slip was lifted out

of the funnel by manipulating the clamp-stand, dropped into the weighing bottle by loosening F, and the retained water was weighed. By replacing D by tubes of different diameters, the effect of the rate of flow was found. Thus :

(i.) 0.0310 gm. water retained when 185 cc. flow through D in 20 sec.
(ii.) 0.0261 gm. water retained when 185 cc. flow through D in 25 sec.
(iii.) 0.0095 gm. water retained when 185 cc. flow through D in 205 sec.

It thus follows that the faster the rate of flow, the greater the amount of liquid retained on perfectly wetted glass. Hence in spraying trees, when the surface tension has been reduced so as to wet the leaves, it is advisable to spray with as much force as possible.

By mounting the slip in the position as shown in the diagram, it was noticed that the " rim " of water was reduced to a droplet adhering to the lowest corner of the slip, none being retained along the edges in " rim " form. The retention of this drop, however, affected the comparability of the results, since the size of the drop was found to decrease as the rate of water-flow was diminished. In experiment (iii.) with the lowest rate of water flow, the drop was eliminated altogether, but the retained water film was so thin as to exhibit Newtonian colours almost immediately. It seemed desirable, therefore, to combine an initial quick rate of water-flow with a method for slowing up the flow as the surface of the water approached the bottom corner of the slip. By this means, it should be possible to prevent the retention of the drop and at the same time ensure the retention of a water film of appreciable thickness on the glass surface. The following apparatus was designed for this purpose, and though it was somewhat tedious and troublesome to manipulate, yet it gave constant results for any given liquid.

The cover slip was replaced by a somewhat thicker slide of glass, 2in. by 1in., in order that the one piece would last throughout the experiments. Three marks were scratched at one corner by a diamond Fig. XIV., the horizontal one was to mark the level of the liquid ; the two others the outline of the tips of the forceps, worked by a brass collar (as previously described), and firmly clamped to a stand at a definite height. Thus the position of the glass was always fixed during the experiments. A vessel, A, Fig. XV., carrying a wide tube firmly wired to a stopper B, was clamped immovably at the neck C. The tube possessed a tap at D with a wide bore, and a small hole was blown in it at E, the edges of the glass being thickened round the hole to prevent widening. The tube was so adjusted that when the glass slide was in position, its lower corner projected just below the top of the tube F as shown. The liquid was filled up

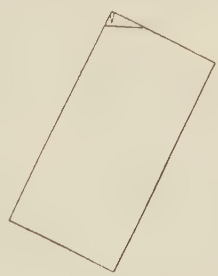

FIG. XIV.

to the horizontal mark on the slip, the temperature being roughly adjusted to 15°C. D was opened and the liquid rushed out until it reached the level F. Here a check was given, further liquid having to flow through the hole E. The lower corner of the slide being passed by the surface of the liquid at a very slow rate, no drop was retained. The slide was further minutely adjusted in each experiment so that the whole time of passing the slide was very nearly 13 seconds by stopwatch. About ten seconds of this were occupied in passing the last one-twelfth inch of slide; and the constant time in each experiment allowed for equal draining of the film on the slide. The slide was then placed in the weighing bottle, and the retained liquid weighed.

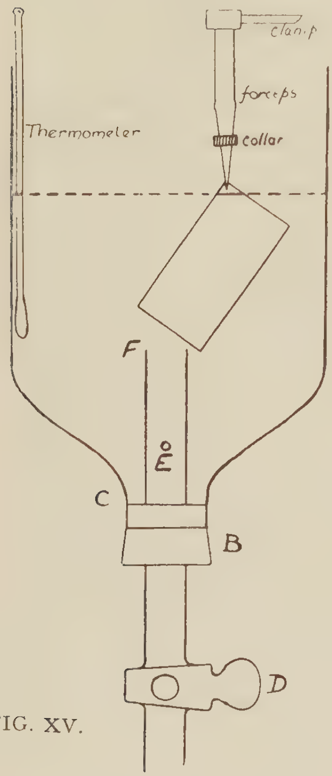

FIG. XV.

The results of nine experiments carried out with water and a previously perfectly water-wetted slide are given below :

(i.) 0.0287 gm.
(ii.) 0.0288 gm.
(iii.) 0.0287 gm.
(iv.) 0.0286 gm.
(v.) 0.0290 gm.
(vi.) 0.0286 gm.
(vii.) 0.0287 gm.
(viii.) 0.0287 gm.
(ix.) 0.0285 gm.

mean=0.0287 gm. ± 0.000027.

The weight of the dry weighing bottle and slide was checked between each experiment, and the above results may be taken as indicating the reliability of the method.

A series of alcohol-water mixtures was investigated by this method from a two-fold point of view, employing in the first place a perfectly cleaned but dry slide (2in. by 1in.) and in the second place the same slide which was perfectly wetted by the liquid under experiment, the conditions for this having been discussed previously. The whole of the results are given in Graph I., but for purposes of discussion the first five results are enumerated in the following table :

Percentage of Alcohol by weight.	Surface Tension. dynes/cm.	Amount (average) retained by perfectly wetted glass. (gm.).	Amount retained by clean dry glass. (gm.).
0.00	76.56	0.0287	0.0146; 0.0084; 0.0188
2.40	66.72	0.0296	0.0110; 0.0152; 0.0182
4.88	58.98	0.0309	0.0178; 0.0252; 0.0262
10.56	50.61	0.0355	0.0347; 0.0325
16.66	45.46	0.0412	0.0413; 0.0412

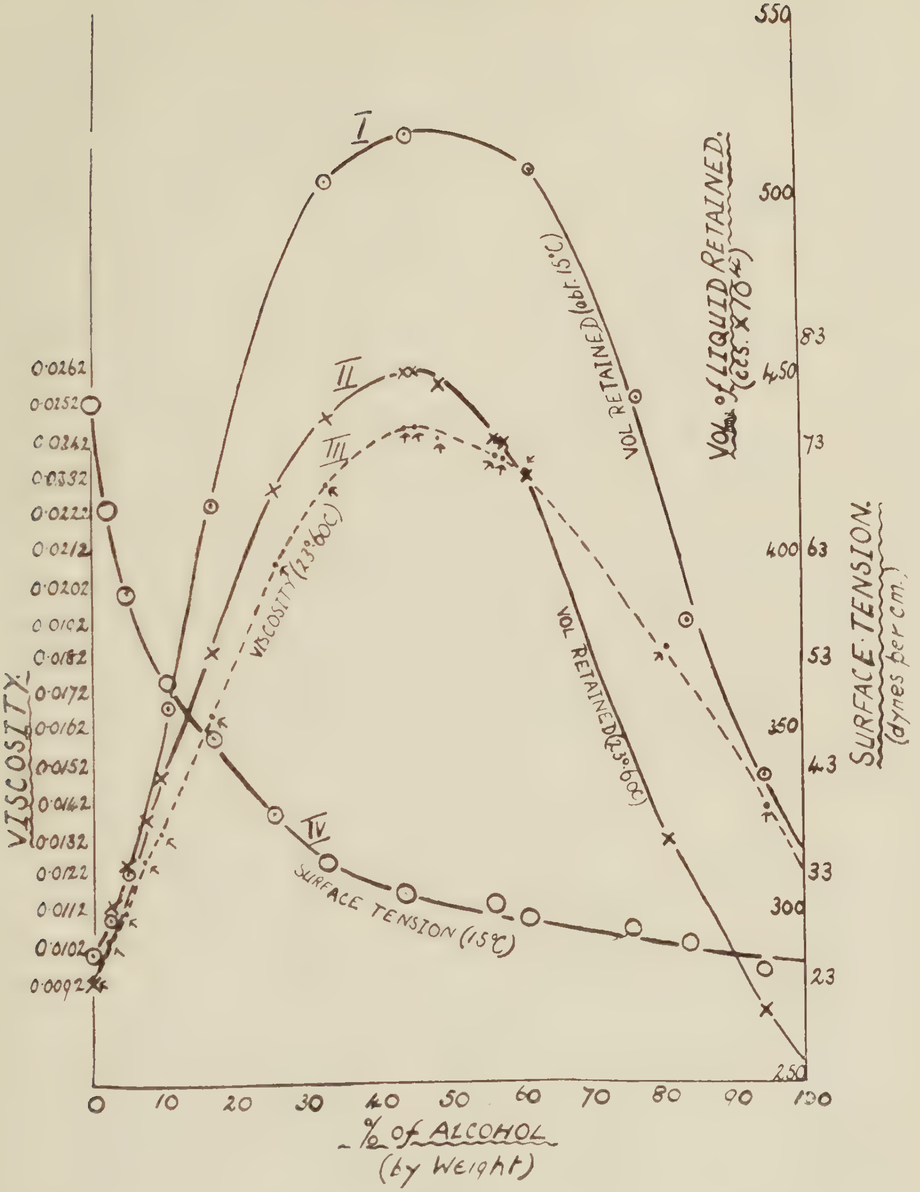

FIG. XVI.

It will be seen that for any given liquid, a maximum and constant amount is retained by the glass surface when it is perfectly wetted by the liquid. When the surface is not wetted, smaller and variable amounts are retained. The results, however, reveal the interesting fact that when the surface tension of the liquid has been reduced to 45-50 dynes/cm., the chemically cleaned dry slide behaved

as if it had previously been perfectly wetted; that is to say, the amount of liquid retained was no longer variable in duplicate trials, and was equal to the amount which would have been retained if the glass had previously been perfectly wetted by the liquid before making the measurement. It thus followed that perfect wetting of the dry slide could be ensured by reducing the surface tension of the liquid below a certain critical value, and it is therefore clear that, when spraying, the maximum amount of liquid cannot be retained by the leaves unless the surface tension is reduced below the critical value requisite for perfect wetting of the leaf surfaces.

On plotting the volumes retained of the alcohol-water mixtures (the densities were determined at 15°C. by a small Ostwald-Sprengel pyknometer), against the composition of the mixtures, a smooth curve (Graph I.) was obtained, having a maximum at about 46 per cent. of alcohol, corresponding to the formation of the compound $C_2H_5OH. 3H_2O$. It was at once seen that this curve possessed in a striking manner the characteristics of the viscosity-composition curve of alcohol and water. In view of this coincidence, the whole series of experiments were repeated (with new apparatus and fresh mixtures) at a constant temperature of 23°60C., and the viscosities of the mixtures were measured at this temperature by means of an Ostwald viscometer, the absolute viscosity of water at 23°60C. being calculated by graphical interpolation. The volumes retained at 23°60C., the viscosities at this temperature, and the surface tensions at 15°C. were plotted against the composition of the mixtures for comparison (see Graphs. II., III. and IV.).

Temperature of Working—23°60C.

The time of flow in this series of experiments was 18 seconds.

Per cent. of Alcohol by weight.	Density of Mixture.	Average amount retained. (gm.).	Average volume retained. (cc.).	Absolute Viscosity.	Remarks.
0.00	0.99740	0.02777	0.02784	0.00922	does not wet dry glass.
2.89	0.99272	0.02970	0.03002	0.01018	,, ,, ,,
4.89	0.98932	0.03090	0.03113	0.01101	,, ,, ,,
7.42	0.98550	0.03190	0.03237	0.01249	,, ,, ,,
9.50	0.98236	0.03300	0.03359	0.01315	nearly wets.
16.80	0.97280	0.03610	0.03711	0.01649	wets.
25.66	0.96064	0.04000	0.04164	0.02080	,,
33.05	0.94826	0.04140	0.04366	0.02298	,,
44.00	0.92662	0.04160	0.04489	0.02460	,,
45.45	0.92358	0.04150	0.04492	0.02460	,,
48.51	0.91702	0.04090	0.04460	0.02428	,,
56.55	0.89880	0.03875	0.04311	0.02386	,,
57.60	0.89638	0.03855	0.04301	0.02377	,,
60.80	0.88908	0.03740	0.04207	0.02342	,,
80.77	0.84124	0.02680	0.03185	0.01851	,,
94.80	0.80450	0.02180	0.02710	0.01403	,,

Graph II. shows that, for binary mixtures of alcohol and water, the volume of liquid retained when plotted against composition gives a property-composition curve with a maximum at C_2H_5OH. $3H_2O$ (approx.) and is very similar to the viscosity-composition curve (Graph III.). The surface tension-composition curve (Graph IV.) is perfectly continuous and seems to bear not much relation to the retention-composition curve. The relation between the viscosity and retention curves is close but not quite absolute. It is clear that the greater the viscosity, the greater the volume of liquid retained, up to a point. Mixtures of high alcohol content deviate slightly from this rule, the anomaly here being due probably to the very low surface tensions (below 30 dynes/cm.) tending to cause spreading to a thinner film. The main point which emerges, however, is that lowering of the surface tension of a liquid ceases to be a dominant factor influencing the volume of liquid retained by a surface, when once the critical surface tension for perfect wetting has been obtained, and that beyond this the important factor governing increased retention is the viscosity of the liquid, increase of viscosity leading to increased retention. In other words, the practice of spraying is most economical when the surface tension of the spray is reduced to that requisite for perfect wetting and no further, and when the spray is made up to have as high a viscosity as possible commensurate, of course, with ease of working.

The experiments were now repeated, using glycerol-mixtures, such solutions being well suited to bring out the effect of viscosity on retention. Graphs V. and VI. show very clearly that once perfect wetting has been obtained, increase in viscosity results in a corresponding increase in the volume of liquid retained.

Per cent. of Glycerol by weight.	Density of of Mixture.	Average amount retained. (gm.).	Average Volume retained. (cc).	Absolute Viscosity.
42.37	1.0983	0.0679	0.06181	0.03381
53.81	1.1298	0.0847	0.07498	0.05733
59.42	1.1440	0.0930	0.08130	0.07656
65.93	1.1635	0.1232	0.10590	0.12130
71.52	1.1805	0.1762	0.14920	0.20450
0.00	0.9974	0.02777	0.02784	0.00922

Temperature of working, 23°60C.

Time of flow, 18 seconds.

Another series of similar trials were now carried out, using soap and gelatine solutions. It was argued that if high viscosity is desirable in a liquid spray, then colloidal protein solutions such as gelatine should be of great value: for in

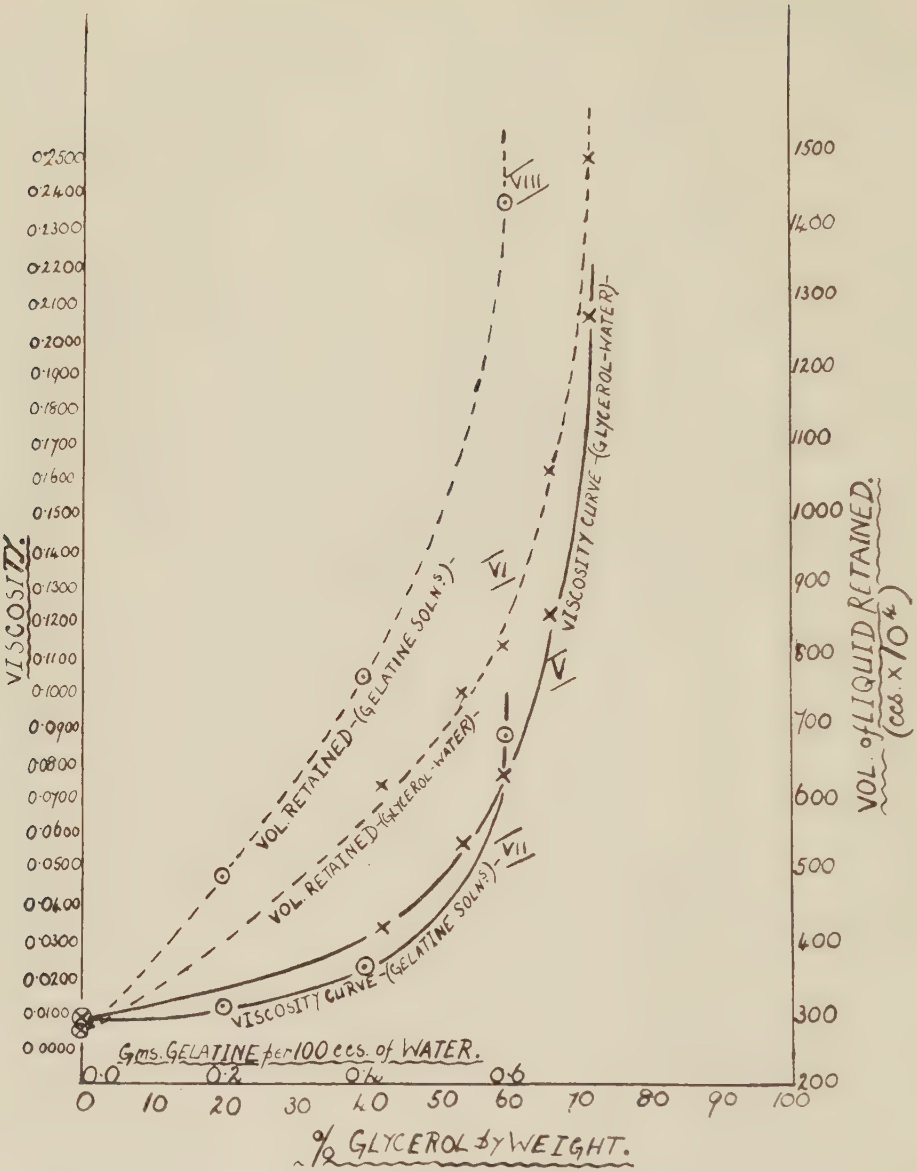

FIG. XVII.

addition to the high viscosity of gelatine solutions, their important protective action on suspended spray materials such as lead arsenate must not be lost sight of. The soap and gelatine solutions were also experimented on in order to investigate the effect of adsorption on the volume of liquid retained by a wetted surface.

Per cent of Soap.	Density of Solution.	Average Amount retained. (gm.).	Average Volume retained. (cc.).	Absolute Viscosity.	Remarks.
0.00	0.99740	0.02777	0.02784	0.00922	does not wet dry glass
0.10	0.99742	0.0347	0.03478	0.00922	wets dry glass
0.25	0.99744	0.0347	0.03478	0.00922	,, ,,
0.50	0.99758	0.0352	0.03528	0.009255	,, ,,
1.00	0.99768	0.0356	0.03568	0.009559	,, ,,
1.50	0.99788	0.0367	0.03678	0.009828	,, ,,
2.50	0.99830	0.0372	0.03724	0.01048	,, ,,

Temperature of working, 23°60C.
Time of flow, 18 seconds.
Solutions 1 day old.

The results for soap solution show that the viscosity does not differ much from that of water throughout the range of concentration used, 0—2.5 per cent. (12). The volumes retained are, however, definitely larger than in the case of water, due probably to adsorption or surface concentration of soap.

Per cent. of Gelatine.	Density of Solution.	Average Amount retained. (gm).	Average Volume retained. (cc.).	Absolute Viscosity.	Remarks.
0.00	0.99740	0.02777	0.02784	0.00922	does not wet dry glass
0.20	0.99798	0.0492	0.0493	0.01203	wets dry glass
0.40	0.99843	0.0767	0.0768	0.02279	,, ,,
0.60	0.99868	0.1431	0.1432	0.08730	,, ,,

Temperature of working, 23°60C.
Time of flow, 18 seconds.

Note.—The gelatine solutions were preserved twenty-four hours before use, since they attain their maximum viscosity after this interval (13). It is thus of advantage to make up gelatine solutions for use with spray materials twenty-four hours before using.

In the case of gelatine, the viscosity rapidly mounts with increasing concentration, and the volumes retained by the glass undergo corresponding increases (Graphs VII. and VIII.). Moreover, on comparing the glycerol and gelatine curves, it will be seen that for glycerol mixtures and gelatine solutions of the same viscosity, a much larger volume of gelatine solution is retained. This is doubtless due to adsorption effects, and the use of an adsorbed protective agent such as gelatine can be advised in making up spray liquids. It must be noted. however, that the limiting concentration of gelatine would be about 0.4—0.6 per cent.; greater amounts would make a spray unworkable, as the solution would probably "set to a jelly." Soap, though invaluable as a simple reducer of

surface tension, is not of much use for increasing the volume of spray retained through viscosity and adsorption effects. It is most likely that the caseinates owe their success in spray liquids to the same factors as operate in the case of gelatine. It should be noted that the results in the cases of gelatine, soap and gycerol were much more difficult to obtain, and are not so accurate, as those for alcohol-water mixtures.

SPREADING OF LIQUIDS ON SOLID SURFACES.

At this juncture it seemed desirable to attempt quantitative measurements of the actual areas which could be covered by definite volumes of a liquid in spreading over a solid surface, and further to find how the areas covered in this way were increased or decreased by altering the surface tension of the liquid. Obviously a surface already wetted could not be used for this purpose. A dry glass surface was therefore utilised, and as such a surface is not perfectly wetted by water, it was possible, by using alcohol as the second liquid, to observe the effect of reduction of surface tension on the areas of spread.

A heavy glass sheet was mounted horizontally on firm iron supports, about three feet from the ground. The most level portion was chosen by means of spirit levels. The sheet was cleaned with hot soap solution, water, alcohol and ether, and polished with silk before every experiment. Preliminary experiments showed that slow delivery from a pipette was the best means of delivering the liquid to the surface, the pipette end being pressed against a fixed spot on the glass in each experiment. Half an hour was quite sufficient for the volume of liquid (1 cc.) to spread to its fullest extent even in the case of alcohol. Loss by evaporation during the experiment was stopped by covering the surface with a large inverted funnel sealed at its narrow end and containing a suspended beaker full of the liquid under observation. The outline of the liquid was then carefully traced on tracing paper placed on the *underside* of the sheet glass and the magnitude of the area determined by means of a planimeter.

It was found that the glass could not be prepared so as to have a standard surface by any method of cleaning ; and thus the same volume of the same liquid was liable to cover widely-different areas when duplicate trials were carried out at close intervals of time. The results, however, whilst only qualitative in character, indicated that both alcohol and soap solution possessed a much greater power of spreading than did water. Thus in one experiment :

1cc. of H O occupied 6.1 sq. cm.
1cc. of alcohol occupied 29.9 sq. cm.

In view of the fact that the glass surface could not be obtained standard, and hence would not give constant results for the same volume of the same liquid,

it was resolved to employ a surface possessing a bigger contact angle with water, in the hope that more uniform results would result.

In the subsequent trials a waxed surface was employed. Such a surface more nearly approximates to that of a smooth highly waxed leaf than would a collodion surface, and it further possessed the advantage of being fairly transparent in thin sheets. Sheets of smooth unruled paper were placed flat in a bath containing "Parowax," kept far above its melting point, so that on pulling out, they only retained a thin film of wax. The sheet with the most even coating was chosen, and its surfaces polished with silk and soft tissue paper. The sheet was then firmly fixed down to the glass plate. Tracing paper could not be used to trace through the wax surface with the glass underneath, owing to faintness of outline. The difficulty was overcome by using a ground glass sheet. This was kept wet, and the areas of spread could then be traced on it. Tracing paper was then used to transfer the outlines from this for the purpose of measurement by planimeter. In order to prepare the wax surface after each observation, the liquid was pipetted off, and the surface carefully blotted and repolished. It was found that with this surface constant areas could be obtained with the same volume of the same liquid at any given time. The alcohol-water mixtures were applied in 10cc., 5cc., and 1cc. volumes, so as to find the influence of the size of the applied "drop" on spread. At about 30 dynes/cm., pipetting the liquid off always left a thin film of liquid clinging tenaciously to the wax; this had to be removed by blotting, and showed that the liquid was wetting the wax. Furthermore, the area occupied by these wetting liquids could be increased at will by applying mechanical force and brushing the liquids over the wax, for they did not recede again. This seems to indicate that in spraying, mechanical force will aid spreading to a large extent when the liquid wets the leaves; hence the spray should be driven into the leaves with force, this tending also to uncurl leaves and to drive drops into any interstices, and also to ensure the maximum retention of spray, as previously shown.

The results, when plotted against surface tension yield smooth curves (Graphs IX., X., and XI.), indicating that reduction of surface tension below 30 dynes/cm. begins to increase enormously the spread. Thus reduction of surface tension from 76 to 32 dynes/cm. means doubling the area of spread approximately; reduction from 32 to 23 dynes/cm., however, more than doubles the area at 32 dynes/cm. Thus, although previously recommending that the surface tension of the spray fluid should not be lowered beyond the point of perfect wetting of the leaves, it must be noted that further reduction of surface tension, while not increasing the volume of spray retained by the leaves, increases the spreading power of the spray enormously, and is thus a desirable feature. Herein lies the value of soap as an economical "spreader."

The results also show that the smaller the volume applied, the greater the area occupied *per cc.* This is an argument for spraying with small drops, which can be obtained by using a low surface tension and a fine nozzle in spraying. It must be pointed out, however, that reduction in the size of drop would lead to decreased " force " in passing the leaves.

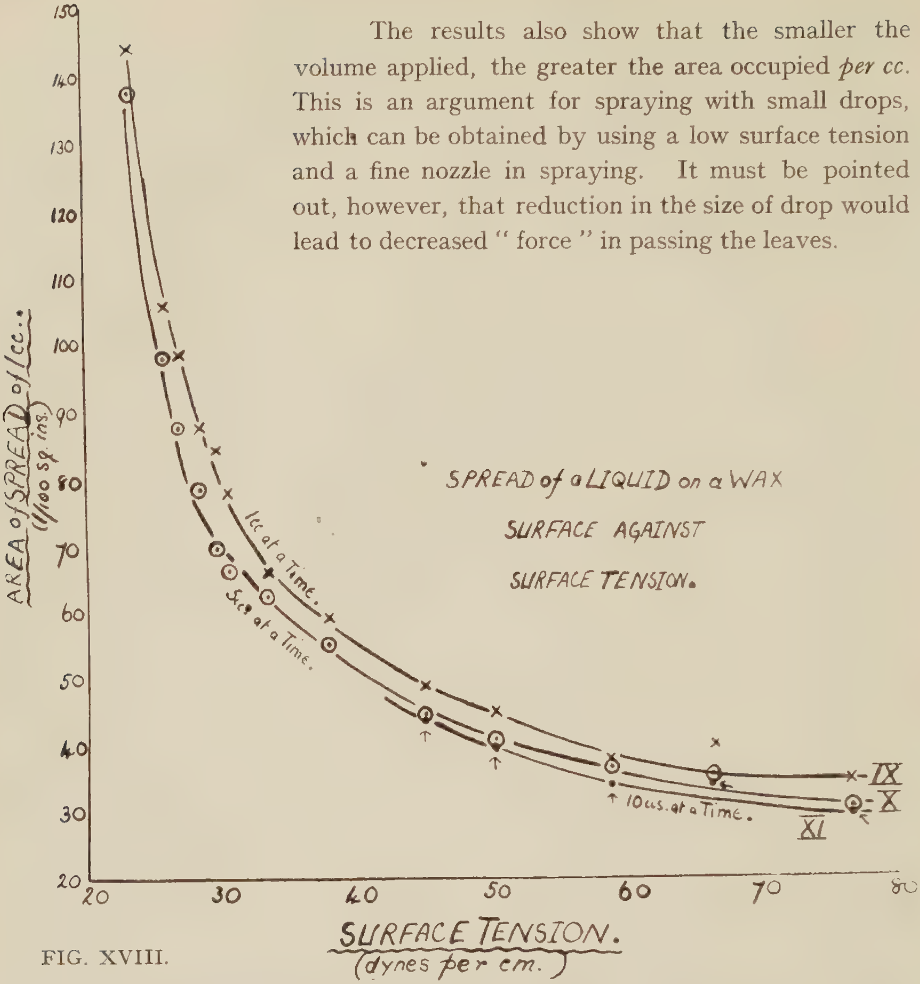

FIG. XVIII.

Per cent. of Alcohol by weight.	Surface Tension. (dynes/cm.).	Roughly at 15° C.		
		Spread of 1 cc. applied 1 cc. at a time. ($\frac{1}{100}$ sq. in.)	Spread of 1 cc. applied 5 cc. at a time. ($\frac{1}{100}$ sq. in.)	Spread of 1 cc. applied 10 cc. at a time. ($\frac{1}{100}$ sq. in.)
0.00	76.56	34.5	30.4	29.6
2.40	66.72	39.7(5) ?	35.1 ?	33.6 ?
4.88	58.98	37.8	36.6(5)	33.9
10.56	50.61	44.9	40.7	39.8
16.66	45.46	48.8	44.5	44.0
25.50	38.36	58.9	55.1	—
32.69	33.84	65.9	62.1	—
44.14	30.95	77.6	65.8(7)	—
56.55	29.99	84.0	69.4	—
61.35	28.70	87.5	78.1	—
76.40	27.41	98.4	87.3(5)	—
83.60	26.12	105.4	97.9(5)	—
94.38	23.53	144.0	137.2(5)	—

Each area is the average of at least three results not differing by more than ½ per cent.; the mixture (alc. 2.40 per cent.) gives unaccountably high results in all three cases.

The writer in conclusion would like to express his thanks to Dr. H. E. Woodman for helpful criticism. Also to R. H. Adie, Esq., M.A., for kindly interest taken throughout the course of the investigation.

SUMMARY.

Comparisons between a smooth leaf surface and glass and wax surfaces have been made by a method described in the text.

By the aid of these comparisons, it has been shown that leaves can be easily wetted by a spray liquid simply by the reduction of the surface tension of the liquid to a certain critical value, this reduction being brought about cheaply by the addition of small quantities of soap.

It has been shown that the maximum amount of spray fluid is retained by the leaves at this critical surface tension; failure to reduce the surface tension to this critical value results in imperfect wetting of the leaves and the consequent retention of variable and smaller amounts of spray fluid; in addition, the spray retained by the foliage "runs up" into droplets, and hence a very uneven coating of spray results

The reduction of the surface tension beyond this critical point *does not* increase the "wetting power" of the spray for the leaves, though it has been proved to add greatly to the "spreading power" of the spray. On the other hand, once the surface tension has been reduced so as to cause perfect wetting of the foliage, increase in the viscosity of the spray fluid causes a corresponding increase in the amount of spray retained as a film by the leaves. For this reason, the use of solutions of gelatine (or the cheaper forms size and glue), twenty-four hours old, and at about 0.3 per cent. concentration, can be advocated; gelatine solutions will not only wet the leaves and cause greater viscosity, but will greatly augment the amount of spray retained by reason of the gelatine adsorbed by the leaf surfaces.

It has also been shown that spraying with force, so that the drops pass through the foliage at a quick rate, increases the amount of spray retained by the leaves.

The areas of spread of *lenses* (1) of liquids on wax surfaces have been measured. The results tend to show that reduction of surface tension of the spray fluid below 32 dynes/cm. greatly increases the area of spread, and prove that soap is therefore probably the best economic "spreader," for dilute soap solutions have very low surface tensions. Small drops applied with great force are likely to spread over the leaf surfaces to the greatest extent.

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THE LEAF AND BUD MITE OF RASPBERRY.

(*Eriophyes gracilis,* Nal.)

By **A. M. MASSEE, F.E.S.**
East Malling Research Station.

FOR some years work has been in progress at East Malling on the classification of Raspberries. In gathering together the detailed records, the incidence of various diseases and pests, some of which are so prevalent on the cultivated raspberry, has been noted.

During the autumn of 1922, whilst engaged in determining pests affecting the raspberry, the writer of this paper came across some very small mites in the buds of the raspberry named Bountiful. This observation led to further investigations, to determine the frequency of the mite, the damage it was doing, if any, and finally the number of varieties of raspberries susceptible. Although, up to the present, evidence is insufficient to make it possible to state whether the presence of this mite seriously affects the fruiting of the canes, it has been noted that some of the mite infected canes dry up before blossoming, during the Spring months.

It may be as well to point out that the disease generally known as "blind canes" so common in some varieties, such as Park Lane, need not necessarily be correlated with this mite. There certainly appear to be other causes of "blindness." A single mite has so far been found on badly blind canes of Park Lane.

Up to the present this mite has been found in the buds of the following cultivated varieties of raspberry. The names have been taken from the classification according to Grubb.*

Baumforth's Seedling B., Hornet B, Superlative, Profusion, Devon, Norwich Wonder, Red Cross, Baumforth's Seedling A, Semper Fidelis, Bountiful, Norwich Market, Penwill's Champion and Helston.

It is interesting to note that Hornet B is attacked to a greater extent than any other variety that has been examined.

The distribution in this country is fairly wide, specimens having been obtained from Kent, Surrey, Essex, Nottingham and Scotland.

This Mite was first recorded by Nalepa,† the Vienesse Zoologist, in the year 1891. It is closely allied to the "Black Currant Bud Mite," and the "Pear Leaf Blister Mite"; it may however, be readily distinguished from the

* Grubb, N. H. "Commercial Raspberries and their Classification." Journal of Pomology, Vol. III., No. 1., November, 1922.

† Nalepa, A. N.Acta Ac. Leop., V. 55, p. 385.

above species by the markings on the shield, which protects the dorsal surface of the cephalo-thorax, and by the position and the length of the bristles placed upon the body. These bristles present one of the chief means of separating the species of this particular group.

This species appears to have been overlooked in this country, and as far as I am able to ascertain it has not been recorded. Below is given a brief description of the mite, and also a summary of its life history and habits as far as they are known.

Description of Mite.

The body is small, oblong, cylindrical, slightly tapering towards its posterior extremity. The length varies in the sexes, the adult male being about $\frac{1}{200}$ inch, and the female $\frac{1}{250}$ inch, the breadth of the mites, in their broadest part, being the same in both sexes. The body varies in colour according to age and season of the year. For example, during the spring they appear semi-transparent, whitish or whitish green, sometimes tinged with yellowish markings; towards autumn, and during their period of hibernation, the colour of the body of the adults becomes reddish-brown, with thoracic shield of a slightly lighter brown colour.

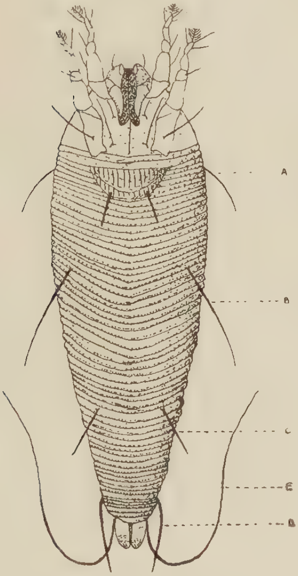

FIG XIX.

The abdomen is marked with about 70-80 transverse rings which are continuous on both ventral and dorsal surfaces. There are two pairs of legs, one pair being situated on either side of the head. Five bristles of varying lengths are situated on each leg, the longest bristle being attached to the ventral side of the basal joint. Three smaller bristles and a feather-like claw are present on the apical joint. There are five pairs of bristles on the body, the first of which (lateral setae, a.), are placed on the side of the body below the thoracic shield. The second pair of bristles (the first ventral setae, b.), are situated on the ventral surface, a little below the middle of the abdomen, and are the longest pair, excepting the caudal setae, which are placed at the posterior extremity of the abdomen. The third pair (the second ventral setae, c.), are short and stiff, and are placed on the ventral surface between the first ventral setae, and the extremity of the abdomen, their actual position being slightly nearer the extremity. The fourth pair of bristles (the third ventral setae, d.), are as long as the second ventral setae, and extend beyond the end of the abdomen. Finally, the caudal setae, (e), placed at the extremity of

the abdomen, are the longest of all. The abdomen terminates in a sucker-like foot, which can be contracted or extended at will. The head mainly consists of a pair of mandibles, and a pair of maxillæ. The thorax is protected on the dorsal surface by a shield, which is marked with three longitudinal furrows, the central furrow forming a median suture. The sides of the shield are punctured and marked by longitudinal branched furrows. Two dorsal thoracic bristles are situated on the shield in its broadest part. The reproductive organ is placed on the ventral surface of the abdomen, in the centre, immediately below the base of the legs, and in line with the first pair of abdominal bristles. Two bristles are situated on the opening. The female reproductive organ is covered externally by a flap.

LIFE HISTORY AND HABITS.

The mites are found in the buds of cultivated raspberries from the months of September to May. So far as the writers' observations are concerned, nymphs and adults may be found hibernating in the buds, but up to the present eggs have not been noticed in any buds. Unlike the Black Currant buds, which become swollen and enlarged after mite attack, the buds of the Raspberry tend to shrivel up, and eventually dry out. The mites are usually found towards the apex of the buds under the bud scales. Sixty or seventy mites may be seen in little groups in a single bud. With experience one is able to discern infected canes. In the Spring, when the buds open, and the flowers form, mites may readily be seen moving about on the stem, flowers and leaves. Observation shows that eggs are laid on the leaves during the spring and summer. As mentioned elsewhere (*) the occurrence of this mite has been correlated with the abnormal foliage frequently found on the raspberry. This however, is not always the case; much dwarfed and deformed material has been examined, and in many cases mites were not present, and when mites were found, there was no evidence to prove they were the cause of the damage.

Schlechtendal† records *Eriophyes gracilis*, Nal., as a pest on the continent of Europe. He describes the disease caused by the mite, and gives an illustration of an affected cane.

Nalepa‡ also records this species from Middle Europe, and remarks that, *Eriophyes gracilis*, Nal., makes whitish marking on the underside of the leaf, deforms the mid vein of the leaf, thus causing the leaf to curl.

I am indebted to Dr. Alfred Nalepa for the identification of the mite.

* Massee, A. M. Gardener's Chronicle, November, 1922.

† Schlechtendal, V. Eriophyidocecidien, Stuttgart, p. 414 (378), 1916.

‡ Nalepa, A. Das Tierreich, Berlin, 1898.

CARBON DIOXIDE IN RELATION TO GLASS-HOUSE CROPS.

DURING the past few years claims have been made by Continental workers that substantial crop increases have been secured by charging the atmosphere in which the plants were growing under glass, with quantities of Carbon Dioxide Gas. Scientific investigation did establish, long since, that the sugar-starch contents of plant-tissue were built up in the leaves from Carbon-Dioxide and water, small quantities of which are always present in the ordinary atmosphere: thus it did appear possible that plants cultivated intensively might be able to make use of Carbon Dioxide gas in larger quantities than is usually found in glass-houses. The problem clearly needed testing and attracted the attention of officials of the Ministry of Agriculture, Research workers of the Experimental and Research Station at Cheshunt and also the Tomato Growers of this country. Aided by a grant from the Ministry of Agriculture, the Cheshunt Experimental and Research Station have been investigating this problem during the past season and have issued two reports on their investigation. Both of these have appeared in the December issue of "The Annals of Applied Biology." Part I. is a report by Owen Owen on "The Distribution of Carbon Dioxide in Glasshouse Atmospheres."

Mr. Owen remarks that "it is generally held that in the open, atmospheric Carbon Dioxide is distributed in layers, the highest concentration being near the soil surface. Under glass, where manurial treatment is comparatively extravagant, one would expect to find this state of things accentuated." Clearly, therefore, this assumption needed testing to ascertain accurate information as to the concentration of atmospheric Carbon Dioxide under glass, and to find out its normal distribution and variations under working conditions. In spite of technical difficulties connected with the sampling of the house gases, without creating undue disturbance, the experimenters secured sufficient information to cast doubt on the above assumption for no atmospheric stratification of the Carbon Dioxide manifested itself, even when the concentration was as high as 30 parts in 10,000.

The Report, Part II., on "The Preparation of Atmosphere rich in Carbon Dioxide," by Owen Owen and P. H. Williams, shows that they were able to secure an atmosphere containing up to 200 parts per 10,000 of air, but that a regular and constant loss of Carbon Dioxide occurs in the house quite independent of the total amount of gas present, and of the presence of soil or plants. The experimenters have not been able to account for this loss. The experimenters were able to record that the average maximum concentration in the presence of

cucumber plants occurs between 4 a.m. and 7 a.m. and the minimum between noon and 3 p.m.

The problem of investigation is naturally surrounded with difficulties, and until the preliminary methods of working have been solved, attempts at determining the crop effects could not be attempted with accuracy. In these experiments the disturbing factors have been so manifest that no conclusions on crop increase are possible.

H. V. T.

FIELD OBSERVATIONS ON THE INCIDENCE OF LEAF SCORCH UPON THE APPLE.

By R. G. HATTON and N. H. GRUBB.

ALTHOUGH it has long been obvious that valuable information on Leaf Scorch could be obtained indirectly from field records, no attempt has been made at East Malling to deal fundamentally with the subject, because no satisfactory means have existed for carrying out the necessary detailed work.

Several of our other investigations (such as Root-Stock, Pruning and Manurial Experiments) have revealed factors tending to modify the incidence and development of Leaf Scorch. The records concerned with this aspect gathered over a period of six years have been collected together and summarised with the object not so much of stating the whole case, or of drawing general conclusions, as of directing attention to these factors, which cannot be ignored in building up a theory as to the causes of the trouble and the most hopeful remedial treatments. The writers have, from time to time, been assisted in the collection of these data by Messrs. G. S. Peren, G. C. Maltby and various members of the present recording staff. These observations culminated in the present year (1924), in the most serious attack of the trouble yet experienced here, which has naturally led to the completion of the picture.

THE INFLUENCE OF ROOT-STOCK.

The first of these factors is the influence of Root-Stock. Soon after the different varieties of "Paradise" had been identified, it was observed that certain of them showed a marked tendency to Leaf Scorch on the young shoots of the stool beds. A row of unpruned specimen "Paradise" Stocks grown for fruiting upon their own roots exhibited the same differences. In both cases, the so-called Improved Doucin (Amelioré Type V.) was outstandingly affected; occasionally the fruiting trees of the True Doucin (Type II.) showed the same tendency to a much lesser degree. In their early years, the young trees on these stocks scarcely showed this tendency at all; in the sixth year (1923) of these Stock trial trees, however, the first signs of "Scorch" were noted.

In the sixth year of the growth of the varieties Bramley's Seedling and Worcester Pearmain, the manifestations were sufficiently striking to warrant the counting of the scorched leaves. These revealed notable differences amongst trees of a single variety, according to the stock on which they were worked. The frequent reduplication of small plots upon the ground, and the interplanting of Bramley and Worcester, sometimes on the same stock, sometimes on different

stocks, side by side, entirely precludes the possibility of attributing the different manifestations to soil variation. On certain plots "scorched" and "unscorched" trees alternate with great regularity according to the stocks upon which they are worked. The following map illustrates the situation:—

Table I.

Map showing arrangement of Trees on Plot XIV.

(*a*)	Bramley on I	Worcester on V	Bramley on I	Worcester on V
	Worcester on V	Bramley on I	Worcester on V	Bramley on I
(*b*)	Bramley on V	Worcester on I	Bramley on V	Worcester on I
	Worcester on I	Bramley on V	Worcester on I	Bramley on V

Both-(*a*) and (*b*) are twice repeated upon this plot in different positions.

In spite of this arrangement, the trees of each variety upon Type V. (Doucin Amelioré) showed more than twice as many "scorched" leaves per tree as those on Type I. (Broad-leaved English). The actual figures are as follows :—

Table II.

Average number of "scorched" leaves per tree, 21/7/1924.
(16 trees in each group.)

Variety.	Root-stock. I.	V.
Worcester Pearmain	34	81
Bramley's Seedling	52	117

The real percentage difference is probably even greater than that shown in the table, since it was estimated that the total number of leaves upon the Type I.'s was considerably greater than upon the Type V.'s. In addition, the detailed records show that the degree of "scorching" was worse upon the trees on Type V.

The same varieties worked upon other stocks, such as the vigorous Type X., showed even less "scorch" than those on Type I., no badly "scorched" leaves at all being recorded. A plot of Lane's Prince Albert, a year older and rather differently arranged, showed an equally striking result. Here the trees are planted as below, and the figures entered on the map speak for themselves.

TABLE III.

Showing arrangement of Lane's Prince Albert Trees on Plot X.

	26		24		22	
S.	V.	S.	V.	S.	V.	S.
	80%		50%		40%	
24	25	12	5	2	6	5
V.	V.	III.	III.	III.	III.	III.
40%	70%	5%	1%	1%	1%	1%

Roman numerals indicate Type of Stock.
Figures above Roman numerals indicate mark based on count of "scorched" leaves.
Figures below Roman numerals indicate estimated per cent. of leaves "scorched."
S. indicates standard trees not included in survey.

A general survey of this Plot, where the trees on different stocks are planted more or less in parallel rows, showed that "scorched" and "unscorched" trees often alternated. This general examination revealed :—

Trees on Type	I.	Broad-leaved English.	Very little scorch.
,, ,, ,,	II.	Doucin.	Some scorch.
,, ,, ,,	III.		Little scorch.
,, ,, ,,	V.	Improved Doucin.	Much scorch.
,, ,, ,,	VI.	Nonsuch.	Very little scorch.
,, ,, ,,	VII.		Considerable scorch.
,, ,, ,,	IX.	Jaune de Metz.	Little or no scorch.
,, ,, ,,	X.		,, ,, ,,
,, ,, ,,	XIII. and XVI.		,, ,, ,,

This was repeated at both the pruned and unpruned ends of the plot.

There is every indication that these results will be generally borne out on a very different type of soil. The early records on our Stock Trial Plot on the Weald Clay in Sussex give the following percentages of "scorched" leaves for three varieties on different root-stocks.*

TABLE IV.

Percentage of "Scorched" Leaves on similar trees on Weald Clay.

On Stock.	Lanes.	Worcester.	Bramley.
I.	(10) 6	(7) 0	(10) 0
II.	(10) 4	(5) 13	(6) 3
V.	(10) 28	(4) 16	(10) 7
Long Ashton No. 5	(8) 0	(10) 0	(8) 0

The figures in brackets indicate the number of trees from which the record has been taken.

Turning to a much older plot of trees at East Malling, the Pruning Plot, we find our results largely corroborated. The trees on this plot are the only ones at the Station bought through the ordinary Trade channels, and little was known

* Since the above was written, very striking confirmation has been obtained from a number of different soils in Hampshire.

about their root-stocks at the time of planting, except that certain trees were on " Paradise," others on " Crab." At least six years ago " scorching " was becoming very evident upon this plot, especially on many of the groups of trees on " Paradise." By means of suckers and root cuttings, a considerable number of these " Paradise " root-stocks have now been identified. Whilst in some cases the varieties of " Paradise " are badly mixed, in at least three instances it seems probable that trees are on pure lines of Types II. and V. As far as the root-stocks are known, these trees only too well confirm the points brought out on the Stock Trial Plots. The fact that these " Paradise " trees are mainly upon those types of stock which we associate with " scorch " makes the comparison of these trees with those on Seedling " Crab " extraordinarily interesting.

The estimated percentage of "scorched" leaves on four varieties on " Paradise " was 53.5, and on the same varieties on " Crab " was only 23.8. Below are given the detailed figures showing that in no instance is the estimated percentage less than twice as great on " Paradise " as on " Crab."

TABLE V.

Showing Percentage of " Scorched " Leaves on Varieties on " Paradise " and " Crab."

(32 trees in each group.)

	" Paradise."	" Crab."
Grenadier	72	36
Gladstone	65	32
James Grieve	61	25
Worcester Pearmain ..	16	2.5

Of course, the relationship of cropping to "scorch," referred to later in this paper, may have an influence contributing to this result. It must not, however, be concluded from this that the trees on Seeding " Crab " are uniformly freer from " scorch." Though the sets of trees on " Crab " were rigidly selected at the time of planting, they show an amazing lack of uniformity as compared with the sets on comparatively true " Paradise." This is well illustrated in the following tables :—

TABLE VI.

Showing estimated percentage of " Scorched " Leaves on Gladstone, unpruned.

Tree No.	On " Paradise " V.	On " Crab " (seedling)
1	70	18
2	80	70
3	80	40
4	80	80
5	80	20
6	90	12
7	100	32
8	100	90

Table VII.

Showing Average Deviation from mean (as percentage of mean) of three varieties on "Paradise" and "Crab."

	Unpruned.		Pruned.	
	"Paradise."	"Crab."	"Paradise."	"Crab."
Grenadier	10	36	36	76
Gladstone	8	56	21	57
James Grieve	23	41	37	50
Average for 48 trees ..	14	47	31	61

This is as striking a demonstration of the difference in variability of trees on "Paradise" and "Crab" as we have yet obtained in our crop records, or any other observations.

At the writers' request Dr. R. C. Knight studied the records from a statistical standpoint. It was found that if it were desired to detect a significant difference of 10 per cent. in the incidence of "Scorch" upon two units of trees, the number of trees necessary in each unit to give us a reliable result would be 15 if the trees were on "Paradise" stocks and 420 if on "Crab." It is recognised that the number of observations is dangerously small for statistical generalisations, but the vast difference in the figures thus revealed cannot be neglected and is clearly of first importance to those engaged in fruit tree research.

It is also interesting to note in passing, that the variability on both "Crab" and "Paradise" is very much greater in this case where the personal factor of pruning is introduced.

Finally, it should be made quite clear that in drawing this comparison between "Paradise" and "Crab," we are *not* referring to the whole class of Layered Stocks as "Paradise," but merely to the types identified upon this particular pruning plot. Observations on other plots appear to reveal many types of Layered Stocks which do not show this characteristic of increasing the susceptibility of the scion to Leaf Scorch.

At the present time we are not prepared to put forward any final explanation of these phenomena. The fact that we have grouped together as "semi-dwarfing" those stocks which we now associate with "Scorch" might suggest a direct correlation between size of tree and "Scorch." It seems hardly possible to hold this view, since the trees on the very dwarfing Metz Stock (Type IX.) show as yet practically no "scorching," also because, amongst the very variable pruning plot trees on "crab" stock there seems no obvious correlation between "Scorch" and size of tree. In the case of the "Paradise" root-stocks, with

which we especially associate " Scorch," namely Types V., VII., and II., we are tempted to point to the type of root system as shedding some light upon the subject. We have always grouped together these root-stocks, the main characteristic of which has been long coarse laterals devoid of fibre. In the case of Type V., the somewhat prolific adventitious rooting around the " collar " does not extend to the laterals.

The fact that scorch frequently manifests itself on trees upon these root-systems is not necessarily a condemnation of the stock, though it certainly suggests that caution must be observed in the general use and treatment of such trees. Under our particular soil conditions we should certainly prefer to eliminate the Type V. stock as being the most susceptible, until we find ourselves able to control the trouble completely through nutritional or other methods ; but at present the Type II. stock fills a unique position, from which its tendency to " scorch " cannot, in our opinion, displace it.

It is most unfortunate that this valuable Doucin Stock (Type II.) is apparently being very rapidly superceded in certain continental areas by the much more easily propagated Type V., which goes under the misnomer of Doucin Amelioré (" Improved " Doucin !).

Varietal Susceptibility.

The trees used in our pruning experiments, already mentioned, have provided material for observations on the susceptibility of different varieties to leaf scorch. It is interesting to note that here again the trees showed little or no signs of the trouble for at least four years after planting.

It would appear, then, that the "scorch " does not, in our conditions, become serious until the trees have reached a certain stage in their development. Moreover, it has tended to become accentuated year by year as the trees have come into bearing.

The remarks already made on the influence of root-stock fully emphasise that the susceptibility of a variety may be altered by this factor, so that, in order to get an entirely satisfactory comparison, the varieties would require to be worked on a uniform layered stock. As a matter of fact, fortune seems to have favoured us to a considerable extent in that the types of " paradise " used for these commercial trees were not only less mixed than we at one time feared, but belonged almost entirely to the " semi-dwarfing " group. Wherever it has become possible to compare the effects of different known root-stocks on these trees, those on Type V. have invariably proved to be the most severely " scorched."

It has been possible to check our results on four varieties by comparing duplicate sets of trees on " Paradise " and " Crab " ; Table V. when analysed

shows that these varieties retain precisely the same order of susceptibility in each case. This has encouraged us to present the full list in detail, partly to provide some guidance to planters and tree raisers, and partly to invite criticism and information.

TABLE VIII.

Showing Order of Susceptibility under our Conditions.

Variety.	Class of Root-stock.	Number and type identified.	Estimated per cent. of leaves "scorched."
Grenadier	" Paradise "	One Type II.	72
Lord Derby	,,	6 type V.	69
Gladstone	,,	9 type V.	65
James Grieve.. ..	,,	13 type V., 1 type II.	61
Beauty of Bath ..	,,	3 type V., 2 type III., 1 type II.	60
Allington	,,	1 type V.	58
Cox O.P.	,,	4 type II., 2 type III.	56
Rival	,,	2 type II.	49
Newton Wonder ..	,,	16 type II.	43
Grenadier	" Crab "	(Seedlings)	36
Early Victoria ..	,,	,,	35
Gladstone	,,	,,	32
James Grieve.. ..	,,	,,	25
Lane's Prince Albert..	,,	,,	19
Worcester Permain ..	" Paradise "	1 type II.	16
,, ,, ..	" Crab "	(Seedlings)	2.5

Each of these percentage figures is based on thirty-two trees.

It is perhaps worth stating how these estimates were arrived at. The writers of this paper carefully examined each tree in turn and accorded each a mark from 0 to 10; from time to time the estimates were checked by actual counts of the leaves on individual branches. No attempt was made to allow for the degree of "scorching"; and with two varieties, Lord Derby and James Grieve, the estimate was somewhat complicated by unhealthy foliage due apparently to other causes. Thus the order might under other conditions be somewhat modified.

Unfortunately time did not allow the completion of the task. Four sets of trees were thus omitted from careful individual records. It was, however, noted that the Early Victoria trees on "Paradise" were almost all badly "scorched," as were the trees of Annie Elizabeth on "Paradise"; those of Bismarck on "Crab" were moderately "scorched"; whilst those of Norfolk Beauty on "Paradise" were as little "scorched" as any variety in the plot.

RELATIONSHIP BETWEEN PRUNING AND LEAF SCORCH.

Perhaps the most interesting of our observations on the Leaf Scorch of the pruning plot is the apparent amelioration of "scorch" as the result of certain

methods of pruning. Reference will be made later to the possibility that this is not a direct result of pruning, but may be brought about by the interference of pruning with the activities of the trees as represented by cropping.

Ever since 1919 it has been noticed that the "scorch" has appeared later and less severely on the trees which are subjected to leader tipping and spur pruning.

The figures already presented, when further analysed from the point of view of pruning, give the results shown in Table IX.

TABLE IX.

Showing Estimated Percentage of "Scorched" Leaves on Tipped and Untipped Trees.

Variety.	"Paradise."		"Crab."	
	Tipped.	Not Tipped.	Tipped.	Not Tipped.
Grenadier	55	89	14	58
Lord Derby	66	72	—	—
Gladstone	44	86	25	39
James Grieve	47	74	11	39
Allington	46	69	—	—
Cox's Orange Pippin ..	54	58	—	—
Rival	34	64	—	—
Lane's Prince Albert ..	—	—	9	29
Early Victoria ..	—	—	16	54
Worcester Pearmain ..	13	19	1	4
Beauty of Bath ..	64	57	—	—
Newton Wonder ..	43	42.5	—	—
Average	47	63	13	37

The outstanding features of this table are, first, that in all cases except the last two, the leader tipped trees were less "scorched" than those not leader tipped. (These two exceptions will be dealt with later.) Secondly, that the difference is relatively greater amongst the trees on "Crab" than amongst the same varieties on "Paradise." At first sight it seems difficult to explain this greater relative difference in the more vigorous trees on "Crab," where one would have expected the results of lack of pruning to be less obvious. This, however, coincides with a similar relative difference in cropping, and we must therefore look at our figures in the light of crop records.

Relationship between Blossom, Cropping and Leaf Scorch.

In reviewing our pruning results we were able to state that in nearly every case leader tipping delayed blossoming and cropping. There were, however, two partial exceptions: Newton Wonder, where in the early years the tipped trees cropped more heavily than those not tipped; and Beauty of Bath, of which,

though none of the trees have cropped well, the tipped trees have regularly blossomed very freely. Curiously enough, it is these two varieties which provide the exceptions in Table IX. We have carried our investigations into this point a step further in an attempt to correlate the Leaf Scorch mark with either number of blossom trusses, or subsequent set of fruit. For this purpose we have chosen Early Victoria as a variety showing the extreme of biennial bearing. Unfortunately we only have the data for this variety on very variable seedling stocks ; and the difficulty of directly correlating a heavy crop with the amount of leaf scorch lies in gauging what would be a relatively big effort for a tree of any particular size. We have included in Table X. the stem girth measurements of the trees, as being the most satisfactory available indication of their size and vigour. We have also included the crop figures for both 1923 and 1924, which indicate the " on " and " off " years of bearing, the former being presumably the trees' " big effort."

TABLE X.

Showing Relation between " Scorch " and Cropping on Untipped Trees of Early Victoria on " Crab."

Tree.	Girth of stem as indication of vigour.	No. of fruits, 1923.	No. of blossom trusses, 1924.	No. of fruits, 1924.	Estimated % of scorched leaves, 1924.
A1 ..	33 cm.	45	1939	1533	60
A2 ..	26 ,,	8	1726	618	100
A3 ..	34 ,,	11	3629	1743	80
A4 ..	18 ,,	9	1022	260	70
A5 ..	18 ,,	9	1055	239	90
A6 ..	26 ,,	1	1997	860	90
A7 ..	21.5 ,,	213	78	95	30
A8 ..	39 ,,	577	46	311(?)	0
C1 ..	17 ,,	187	15	60	0
C2 ..	27 ,,	67	1408	822	80
C3 ..	32 ,,	209	522	643	80
C4 ..	29.5 ,,	287	22	42	20
C5 ..	32 ,,	9	1712	1275	90
C6 ..	28 ,,	491	8	32	Trace
C7 ..	30 ,,	1	1729	1185	70
C8 ..	40 ,,	14	1677	1790	0

There are here ten trees more or less badly " scorched " in 1924, and six slightly or not at all " scorched." Of the ten badly " scorched " trees every one cropped much more heavily in 1924 than in 1923, i.e., 1924 was their " on " year ; of the other six trees, five cropped more heavily in 1923 than 1924, i.e., 1924 was their " off " year.

This kind of evidence is apparent, if not always in so striking a degree, in the great majority of cases which we have analysed. Here and there exceptions

like tree C8 in the table do occur ; if there is really a connection between the crop of blossom or fruit borne by the tree and its tendency to "scorch," as we are inclined to believe, these exceptions may be capable of one of the following explanations. The mixture of root-stocks on this plot may be quite enough in itself to account for them ; for, under our conditions, certain of the named root-stocks, when worked with Bramley, Worcester, and Lane's, have up to the present shown no "scorch" at all.

Further, it has been noticed on this plot, as well as on certain other plots, where observations have been made, that the headland trees are often less "scorched" than those in the interior of the plots ; tree C8 (Table X.) is the second tree from the headland. And again, although our soil is on the whole exceptionally uniform, it is impossible entirely to eliminate this factor.

Additional evidence which points to a correlation between blossoming or cropping and the tendency to "scorch" can be drawn from Table IX. Thus the two varieties on "Paradise" showing the greatest reduction in "scorching" from tipping, Gladstone and Rival, are precisely those two which have cropped most lightly on the tipped trees. Again, it has already been pointed out that the reduction of "scorching" on the tipped trees is greater amongst those worked on "Crab" than amongst the same varieties on "Paradise." This phenomenon can be explained on the same hypothesis, since the reduction of cropping due to tipping is relatively much greater amongst the trees on "Crab" than amongst those on "Paradise."

One more bit of evidence, which seems to favour this idea, that it is cropping rather than pruning which influences the amount of "scorch," is the observation made that the unpruned trees of Lane's Prince Albert on known stocks, which were in their "off" year, showed less "scorching" than the duplicate pruned set, most of which were yielding their first considerable crop.

If one takes into account the nutritional aspect of leaf scorch, and the potash factor recently brought to light by Mr. Wallace, of Long Ashton, the high percentage of potash shown by most analyses of the ash of apples is extremely significant.* Gourley, in his *Textbook of Pomology*, states that : "The ash of apples averages over one-half of potash, not unlike the other fruits ; however, the analysis shows rather more variation for ash than has usually been noticed in the fruits in general." A rather similar statement is made by Gardner, Bradford and Hooker in *Fundamentals of Fruit Production*.

A factor in the behaviour of leaf scorched trees as yet unexplained, namely the uneven distribution of "scorch" amongst the individual branches of particular trees, has shed a sidelight upon a different aspect of the reaction between "scorch" and yield of fruit. The fruit from "scorched" and

* Annual Reports Agric. & Hort. Research Station, Long Ashton, 1921, 1922, 1923.

"non-scorched" branches of certain trees of Newton Wonder and Allington Pippin was picked and recorded separately; in every case that from the "non-scorched" branches was materially larger than the rest, the difference being sometimes as much as fifty per cent.

COMMERCIAL METHODS OF MANURING AND LEAF SCORCH.

The writers of this article have made no attempt to go fundamentally into the problem of nutrition in its relation to Leaf Scorch. The work of Mr. Wallace along this line has already been referred to, and has doubtless been followed with keen interest by readers of this *Journal*.

Our observations here are in the nature of a criticism of a field practice, typical of certain districts, and appear worth recording from that point of view.

Some growers have been apt to attribute leaf scorch to general starvation, and they have been disappointed, like ourselves, when they have failed to eliminate the trouble after repeated dressings of organic manures. Our pruning plot, which we have already shown to be suffering severely from Leaf Scorch, has been given what would ordinarily be called "generous" treatment. The following is the chronicle of its dressings since 1919.

1919. 15 tons London Dung per acre.
10 cwt. Potash Flue Dust per acre.
1920. 30 cwt. 8% Black Shoddy per acre.
10 cwt. best ground Lime per acre.
1921. 15 tons London Dung per acre.
4 cwt Bone Siftings per acre.
1922. 15 tons London Dung per acre.
1923. 30 cwt. 7%—8% Black Shoddy per acre.
4 cwt. Sulphate of Potash per acre.
(applied to half the trees of each variety).
1924. 12 cwt Meat and Bone Meal per acre (in two dressings).
4 cwt. Peruvian Guano per acre (summer dressing).

It will be seen that the dressings have been up to the present predominantly nitrogenous. In the light of Mr. Wallace's work it would appear that many of these dressings have been worse than useless, since by their very nature and persistence they have only tended to destroy the balance between the various constituents of plant food.

On the other hand, under our soil conditions, complete starvation does appear, at any rate in the early stages, to accentuate the trouble. The number of "scorched" leaves has been recorded upon duplicated plots of trees on known stocks, some of which have received nothing but the annual ploughing in of a non-leguminous green crop, whilst others have been manured similarly to our pruning plot. The figures speak for themselves.

TABLE XI.

Showing the Average Number of "Scorched" Leaves per Tree.
(8 or 16 trees in each group.)

	Manured. (Plot XIII.)	Unmanured. (Plot XIV.)
Worcester Pearmain on Type I. ..	12.5	34.0
" " " V. ..	44.7	81.0
Bramley's Seedling on Type I. ..	38.9	51.7
" " " V. ..	82.0	117.3

The nutritional question must then be fully considered in all methods of amelioration in the field.

Since this side of the question is obviously so important, we give below a typical chemical analysis of our soil made in 1913 by the late Mr. L. E. Holyman, of the South Eastern Agricultural College, Wye.

TABLE XII.

Typical Chemical Analysis of Soil at East Malling.

	Soil.	Subsoil.
Moisture	1.067	1.066
Organic Matter	3.386	2.033
Nitrogen	.1047	.1400
Carbonate ($CaCO_3$)	.354	.352
Potash (K_2O)	.2951	.316
" available	.024	
Phosphoric Acid (P_2O_5) ..	.1117	.073
" available	.0296	

Our observations upon root-stock, pruning, and cropping all seem from the Pomologists' standpoint to indicate certain disturbances in the "balance" of the tree, the restoration of which can only be accomplished as the Physiologist and Chemist define that "balance." It is to be hoped that these observations may contribute something from the field aspect.

SUMMARY.

Observations upon Apple Leaf Scorch in the field have shown :—

1. The variety of root-stock strongly influences the development of leaf scorch.
   (*a*) Amongst the layered stocks, three varieties, all classed as "semi-dwarfing," are notable for their tendency to increase the "scorch."
   (*b*) Amongst the seedling "crab" or "free" stocks there is very great variability; but when compared, on the average, with two of the above-mentioned "semi-dwarfing" varieties, they show distinctly less tendency in this direction.

(c) These manifestations of varying susceptibility to "scorch" have been noted on the unworked stocks themselves, and on very different types of soil.

2. Different varieties consistently show different degrees of susceptibility to Leaf Scorch. The order of susceptibility of the only four varieties available for comparison proved to be identical on layered and seedling roots.

3. The practice known in pruning as "leader tipping" has consistently tended to reduce the "scorch."

4. There appears to be a direct relationship between blossoming and fruiting, on the one hand, and Leaf Scorch on the other. This may account for the effect of leader tipping noted above.

5. The Leaf Scorch appears directly to reduce the size of the fruit.

6. Whilst on young trees lack of organic manures has tended to accentuate the "scorch," on older trees generous feeding with organic (predominantly nitrogenous) manures has by no means checked the trouble.

THE PHYSICS OF SPRAY LIQUIDS.

II.—THE PROTECTIVE ACTION OF VARIOUS SUBSTANCES ON LEAD ARSENATE SUSPENSIONS.

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INTRODUCTION.

THE general study of the formation and stability of emulsions and suspensions is of the greatest practical importance to horticulturists and, in particular, an important problem confronting the sprayer is the preparation and stabilising of lead arsenate suspensions.

No really " systematic attempt has been made to arrange the various emulsifying agents in the order of their capacity to promote and maintain stable emulsions " (1) ; even less work has been done on the protective action of substances on suspensions.

The phrase " protective action " simply means the power of a substance to prevent sedimentation of the solid particles of a suspension ; thus the particles of lead arsenate quickly settle from the unstable suspension formed by shaking lead arsenate with water. The presence of some third substance, usually colloidal in nature and termed a " protective agent," exerts a protective action on the suspended lead arsenate particles and prevents sedimentation.

It is usual in practice to designate by the term " spreader " all substances which are added to spray liquids either to promote and maintain stable emulsions and suspensions, or to lower the surface tension of the liquid in order to make the spray fluid wet, and spread over, the leaf surfaces. It should be pointed out, however, that where a substance is added to a spray (as caseinates are often added to lead arsenate), for the purpose of promoting and maintaining or stabilising emulsions and suspensions, the added substance is really an emulsifying or suspending agent, exerting a protective action on the emulsions and suspensions when formed. Thus these latter substances are not primarily " spreaders " though they do lower surface tension to a small extent and thus cause wetting of, and spreading on, the foliage. As an example, soft soap, which is a good " spreader " in the true sense that it greatly lowers surface tension and thus causes wetting of, and great spreading on, solid surfaces (2), has been proved in these experiments to be not nearly so good a protective agent as gelatine, which, in turn, is far inferior to soap as a true " spreader."

The present paper is not concerned with the powers of wetting and spreading, but merely with the protective action exerted by various substances on lead arsenate suspensions.

USE OF LEAD ARSENATE IN SPRAYING.

As Pickering (3) and Fryer (4) have pointed out, calcium arsenate, the cheapest form of arsenic effective as a poison, has been proved by extensive practical trials to be liable to cause scorching of foliage ; that calcium arsenate cannot be recommended for spraying fruit trees is to be expected from its relatively high solubility.

Lead arsenate can be manufactured (as the triplumbic salt), so that only traces of soluble arsenic are present ; this accounts for its use as an insecticide to the exclusion of practically all other stomach poisons.

There is, however, one great disadvantage attaching to the use of lead arsenate : on account of its high density it rapidly settles from its admixture with water. An important requirement of a lead arsenate spray fluid, therefore, is that the arsenate should remain in suspension as long as possible in order to produce an even coating on the foliage.

There are three possible methods of overcoming or partially overcoming this difficulty. The first method is to prepare the arsenate in a fine form, for then the particles will remain in suspension in water alone much longer ; Fryer (4) mentions an arsenate prepared in this way. The second method is to agitate the mixture of arsenate and water vigorously by mechanical means The third and most general method is the use of the so-called protective agents.

PREVIOUS EXPERIMENTS.

Lovett (5) weighed out equal amounts of lead arsenate, shook them with solutions of known concentrations of the suspending or protective agents in exactly similar cylinders and then measured the rate of settling by reading the volume of sediment at various times. This gave a qualitative idea as to the best protective agents for use with lead arsenate ; the method cannot be accurate for, as will be shown later, it does not take into account the possibility of reaction between the arsenate and the protective agents causing precipitation of substances of a more flocculent nature than coarse lead arsenate ; the possibility of the deposition of arsenate in a more bulky form by some protective agents ; and the possibility of sedimentation of the protective agent itself.

Fryer (4) has used the rate of settling of lead arsenate sediments for comparing the capabilities of different " types " of lead arsenate to remain in suspension, his method being to photograph the cylinders at different times. Parker and Long (6) photographed the coatings of lead arsenate left on glass and leaves by spraying these surfaces with lead arsenate suspensions with and without the addition of calcium caseinate. Fryer (4) has also photographed the coatings of different " types " of lead arsenate on leaves.

SCOPE OF PRESENT INVESTIGATION.

In spraying, the paste form of precipitated lead arsenate is generally used, for it is said that the drying of this gives a coarse powder not easily wetted again.

The present investigation was concerned with an ordinary dry commercial sample of lead arsenate as supplied to a chemical laboratory. Its previous history was unknown and it was found to contain much coarse powder ; but as the lead arsenate used throughout the series of experiments came from the same well-mixed stock quantity this was not a disadvantage. It was rather an advantage to use a dry form such as this containing all gradations of particles from very fine to coarse ; for in the first place the *dry* arsenate strictly tested the capability of the protective agents to wet the dry material and promote suspensions and, in the second place, the use of an amount of arsenate largely in excess of that which could be brought into suspension and protected by economic concentrations of the protective agents sharply differentiated the promoting and protective powers of the agents. For it must be premised that if a protective agent can promote and stabilise suspensions containing particles of a certain size, it can with ease promote and stabilise suspensions of the same material containing particles of smaller dimensions; therefore the best promoting and protective agent is one which can promote and stabilise suspensions of particles of the largest size. It follows from this that a good and a bad protective agent may fail alike to form stable suspensions of a substance and yet may both alike promote stable suspensions of *fine* particles of the same substance ; in order to differentiate between the two it is necessary to make experiments on a large excess of the substance containing all gradations of size of particles.

It may be stated here that at all the dilutions of protective agents used in this series of experiments, the coarsest particles of lead arsenate fell almost instantaneously as a sediment ; every agent, therefore, had a thorough testing.

EXPERIMENTAL.

The solution of the protective agent was placed in a thermostat at 23° 60 C. till it attained that temperature, and was then immediately used.

35 gm. (i.e., a large excess) of lead arsenate were placed in a litre flask ; the solution of the agent at 23° 60 C. was added with constant shaking of the flask until the litre mark was reached. After a vigorous shaking, 450 c.c. of the mixture were placed in each of two exactly similar 500 c.c. cylinders, which were kept in a thermostat at 23° 60 C. The volume of sediment, and the amount of " clearing " at the top of the suspension were read from time to time. At definite times, fractions of the suspensions were carefully syphoned off into filter flasks (by means of a water pump) through a tube which, passing

through a large flat cork, allowed firm adjustment of the lower end of the tube at any desired graduation on the cylinder. (Fig. XX.).

An example may make this clearer ; supposing it were desired to syphon off the two top 150 cc. fractions from a suspension at the expiration of a certain time. The tube was adjusted so that its lower end stood level with the 300 cc. graduation mark on the cylinder, and the fraction 450-300 cc. was carefully syphoned off by turning on the pump. The process was immediately

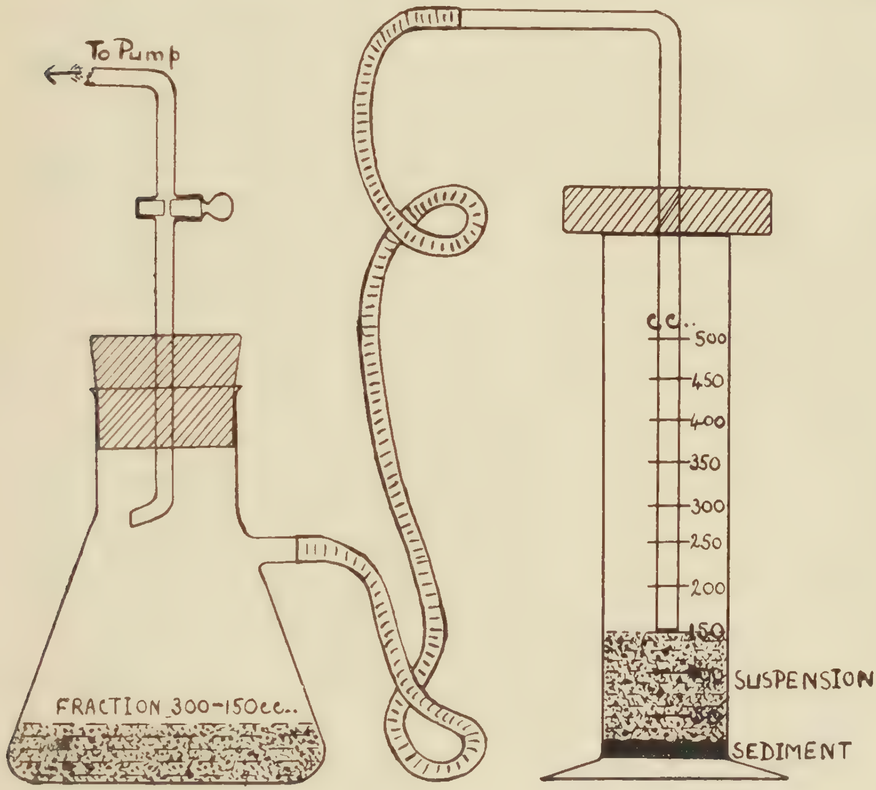

FIG. XX.

repeated with the next 150 cc. fraction, syphoning into a fresh filter flask, the two processes occupying scarcely a minute with deft manipulation. The remainder of the suspension was discarded, the same fractions for longer periods of standing being procured from the similar cylinder running in parallel experiment.

In no case was a fraction taken so as to include arsenate sediment.

It was desired now to get some quantitative idea of the amount of lead arsenate in the various fractions so obtained. Heating to dryness and weighing the residue, or estimation of the lead in the sediment, were both possible methods.

Both were tedious operations, and were abandoned in favour of "weighing" the lead arsenate by density determinations; the last method, though great accuracy could not be claimed for it, was a very quick comparable method.

The density of a suspension which is probably very heterogeneous as regards size of suspended particles, cannot be determined with anything approaching accuracy in a pyknometer, which has a very fine inlet tube. It was therefore decided to weigh the same volume of the fractions in every case in a 50 c.c. specific gravity bottle (Fig. XXI.).

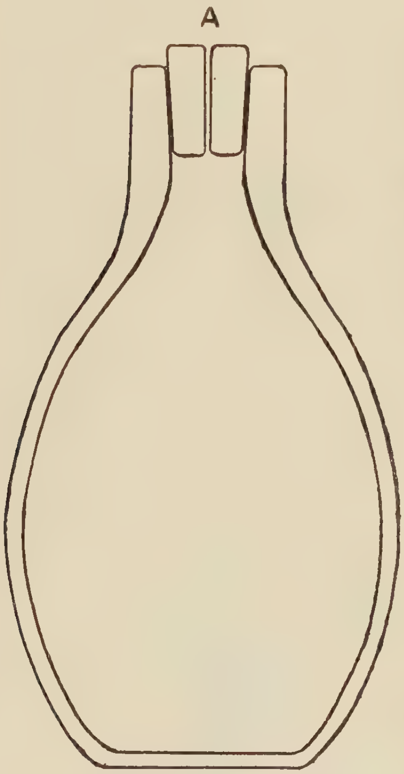

FIG. XXI.

The fraction was warmed to 23° 60 C. in the thermostat, shaken to obtain a uniform sample and rapidly poured into the bottle so that the liquid overflowed. The stopper of the bottle was then quickly inserted before sedimentation was possible, and the excess suspension flowed out through a hole (A., Fig. XXI.) bored centrally through the stopper. The bottle was placed in the thermostat at 23° 60 C. for a few minutes, withdrawn, wiped dry and weighed.

The weight of the same volume of the solution of the protective agent was then found in a similar manner. The difference between the two weights gave a rough but comparable quantitative measure of the amount of arsenate suspended in an average 50 c.c. of the 150 c.c. of the suspension; multiplication of this amount by three gave the total amount of arsenate in the fraction.

Two sources of error are apparent; one is the settling out of unknown amounts of the protective agent with the sediment, and allows of no easy correction; the other is due to the volume occupied by the suspended lead arsenate; this latter correction was not applied as it did not alter in the least the positional differences of the figures in Tables A. and B., but merely accentuated the observed differences.

The results for differing concentrations of the protective agents are given in Table A; Table B shows the amount of lead arsenate in the top 300 c.c. layers of 450 c.c. columns of suspensions (protected by 0.5 per cent. protective agent) in exactly similar cylinders for times 10 min., 2 hr. 45 min., and 21 hr.; Table C.

shows the volume of sediment and the "volume of clearing" of the suspension at different times.

EXPERIMENTAL DETAILS AND DISCUSSION OF RESULTS.

WATER ALONE. The higher value in the top fraction of the 21 hr. series (Table A) was due to surface attraction; a film of the arsenate collected on the surface and hence gave a small but relatively large error. Water alone is of no use for forming lead arsenate suspensions, even for 10 min.

SOAP SOLUTIONS. The soap used was a hard one sold commercially as a "cereal" soap and was recommended for trial by Prof. T. B. Wood, F.R.S. This soap gave no protein tests and was found to contain no nitrogen; hence the expectation that it would contain (colloidal) protein matter from the cereal refuse supposed to be used in its manufacture was not realised.

Reference to Table B shows that at 0.5 per cent. concentration the soap was the worst protective agent used, or more truly the worst promoter of suspensions, if it be postulated that the first column of Table B at time = 10 min. after formation of the suspension is really not a test of capability for stabilising the suspensions, but a test of power of *promoting* suspensions. The effect of standing the suspension with 0.5 per cent. soap for considerable times (*i.e.*, really the power of the soap to maintain or stabilise the suspension when once formed), was not done owing to serious disadvantages found to attend the use of soap. The protective action was bad, however, even in the case of 1 per cent. soap (Table A).

The soap solutions were prepared by dissolving the weighed quantity of soap in 200 c.c. of hot distilled water and then making up to 1000 c.c. at 23° 60 C. They were found to be very alkaline to litmus, indicating the presence of free alkali in the solution. On shaking with lead arsenate the alkalinity was considerably reduced and, in the case of 0.5 per cent. soap solution, disappeared altogether. A reaction between the sodium hydroxide and the arsenate was therefore suspected; this suspicion was strengthened by observations on the bulky sediment. For, though the sediments at 2 hr. 45 min. and 21 hr. in the case of 2 and 3 per cent. soap solutions were much larger than the corresponding ones for 0.3 and 0.5 per cent. gelatine, yet the amounts of arsenate in suspension were also larger, tending to prove that the lead arsenate was converted by some reaction to a more bulky substance (Tables C. and A.).

An obvious possible reaction is:

$$Pb_3\,(AsO_4)_2 + 6NaOH = 2\,Na_3AsO_4 + 3Pb\,(OH)_2,$$

the lead hydroxide probably accounting for the bulkiness of the precipitate. After standing a suspension about two days, the supernatant liquid was poured off, centrifuged for an hour and filtered till perfectly clear. The filtrate gave strong arsenate tests indicating the presence of soluble arsenic. As a more conclusive

proof that the above reaction is possible, a dilute solution of sodium hydroxide was shaken with lead arsenate. The supernatant liquid, which was now neutral, was decanted, centrifuged and filtered. The filtrate gave strong arsenate tests, indicating the formation of soluble sodium arsenate by the above reaction. The filtrate obtained in a like manner by shaking lead arsenate with distilled water gave only the slightest indications of arsenate reactions, proving the absence of all but traces of soluble arsenate in the sample of lead arsenate used.

The use of soap as a protective agent for lead arsenate, therefore, gives rise to the formation of soluble alkaline arsenates which, of course, are very liable to scorch foliage.

In addition to the above reaction, the reaction :

$$Pb_3\,(AsO_4)_2 + 6\ R.COONa = 2\ Na_3AsO_4 + 3\ (R.COO)_2\ Pb,$$

where R.COOH is a higher fatty acid, possibly takes place. This reaction tends to form soluble arsenate and also adhesive lead soaps, the latter clogging the nozzles of the spraying outfit.

The sediment from the suspension was boiled with distilled water, centrifuged for an hour and the liquid decanted. The process was repeated about eight times to ensure removal of all soluble sodium soaps (R.COONa) from the sediment. The latter was then collected on a filter paper and, after being well washed with boiling water, was suspended in distilled water in a separating funnel and hydrochloric acid solution (1 of conc. to 4 of water) added till definitely acid. Ether was then shaken with the mixture and the ether solution separated and washed free from acid. On evaporation of the ether a white solid fatty substance remained. This contained C, H and O only, melted easily, floated on water, dissolved in aqueous sodium hydroxide to give a lathery solution, dissolved in solvents such as ether and chloroform, and permanently stained paper. It was therefore a fatty acid probably formed by the action of the hydrochloric acid on an insoluble lead soap ($(R.COO)_2$ Pb) in the thoroughly-washed sediment.

It must be noted that all soap solutions on sufficient dilution yield free alkali and " acid soaps " by hydrolysis (7) ; some acid soaps are practically insoluble even in hot water (8), and hence these may have been the cause of fatty acid having been obtained from the insoluble sediment, and of the increased bulk of the sediment. Fryer (9) points out that in using soap with a spray fluid one must allow for the " hardness " of water ; it is necessary to add that if the soap be of small concentration, insoluble acid soaps are liable to be formed to some extent.

Gelatine Solutions. The weighed amount of gelatine (Coignet's " Gold Leaf ") was soaked overnight in distilled water and then dissolved by the aid of gentle heat and constant stirring. The solution was then diluted to 1000 c.c. at 23° 60 C. The foam which separated at the top of the suspensions in the cylinders and went solid was carefully removed in all cases.

Reference to Tables A, B and C shows that gelatine is the best promoting agent and protective agent at 0.5 per cent. concentration during the period of testing (21 hr.). 0.3 per cent. gelatine showed a slightly better protective action during the first three hours for some reason.

In addition to the above, gelatine has certain other advantages; in the first place, owing to the high viscosity of gelatine solutions and the great adsorption effects large amounts of the spray will be retained by the foliage during spraying, thus preventing loss of liquid by dripping from the leaves (2). In the second place 0.3 or 0.5 per cent. gelatine will easily wet most leaves and the resulting deposit will not be washed off by rain or blown off by wind. This is due to the insolubility of gelatine in cold water; once a film of mixed gelatine and arsenate has dried on the leaves (and gelatine has admirable "adhesive" or "sticking" properties as shown above) the gelatine will merely tend to swell up under the influence of water by a process known as imbibition. Hence the gelatine will not redissolve in (cold) rain water and drip from the leaves, carrying with it the lead arsenate, as a caseinate film would.

Gelatine has possibly two disadvantages; the first is that unlike calcium caseinate it is insoluble in cold water and thus a suspension made with its aid entails more trouble in preparation than one made with caseinate*; this disadvantage, however, becomes a decided advantage once the suspension is made, as shown above. The second possible disadvantage is that gelatine might prove to be dear, though 0.3 per cent. would be only at the rate of 3 lb. per 100 gallons of spray fluid. This disadvantage could be overcome to a certain extent by using crude products such as size or glue.

DEXTRIN SOLUTIONS. The weighed quantity of dextrin or British Gum was gently warmed with 200 c.c. of distilled water with constant stirring until dissolved; the solution was then made up to 1000 c.c. at 23° 60 C.

0.5 per cent. dextrin is the fourth in order of promoting arsenate suspensions (Table B), though it is far in advance of the sixth (sodium caseinate), being much more comparable with gelatine and calcium caseinate. That it forms a fairly stable suspension is shown by the fact that it moves to third place in the list of protective agents after the suspensions are 21 hr. of age.

The negative amounts of lead arsenate shown for certain dextrin suspensions and for other protective agents in Tables A and B mean that the fractions are almost clear of arsenate and that the protective agent has been deposited with the sediment. In no case is the amount of protective agent in the original corresponding 150 c.c. of protective solution equalled by the negative weights recorded. It should be noticed (Table A) that larger negative amounts of "arsenate" are recorded for the larger concentrations of protective agents,

* A strong solution of gelatine would first be made by heating with a gallon or two of water and this added *whilst hot* to the main portion of the spray fluid.

tending to prove that these negative amounts are due to deposition of protective agents. It is also likely that those suspensions showing the negative amounts have still a little arsenate in suspension, and more than with water alone probably, the fact being masked by deposition of protective agent.

STARCH SOLUTIONS. The starch was ground up with water to a thin paste in a mortar and poured into boiling water which was kept stirred, the remaining paste in the mortar being washed into the solution. The 0.5 per cent. starch was prepared in two ways; in the first the starch solution when formed was not boiled; in the second the starch solution was boiled for a few minutes after formation with constant stirring.

The results indicate that when the starch is not boiled immediate precipitation of the starch and arsenate in a very flocculent form takes place. Even when well-boiled the sediment at 5 and 10 in. min the case of 0.5 per cent. starch is greater than the flocculent precipitate for 0.5 per cent. soap (Table C), and yet the arsenate suspended in the former case is much larger in amount than in the case of the soap suspension, showing that the volume of sediment is no criterion of the stability of the suspension.

Well-boiled starch is quite as good a promoter of arsenate suspensions as dextrin at the same composition (Table B); It is not quite so good a protective agent for 21 hr., but for 3 hr. it ranks next to gelatine.

SODIUM CASEINATE SOLUTIONS. (*a*) 5 gm. of casein (commercial) were slowly stirred into 200 c.c. of a boiling solution of sodium hydroxide containing 0.94 gm. of hydroxide. The mixture was boiled until a clear yellowish solution was obtained and was then made up to a 1000 c.c. at 23° 60 C., so that it was 0.5 per cent. as regards casein. The solution so prepared was very alkaline to litmus; (*b*) 3 gm. of casein and 0.564 gm. of sodium hydroxide; the above process was repeated the solution being 0.3 per cent. as regards casein and alkaline to litmus · (*c*) 1 gm. of casein and 0.188 gm. of sodium hydroxide; the above process was again repeated, the solution being 0.1 per cent. as regards casein, and showing only the very faintest alkaline reaction with litmus.

The 0.5 per cent. solution yielded a suspension which gave a precipitate as bulky as that from the soap in the first 10 min., this "settling down" later. The promoting power was only a little better than that of 0.5 per cent soap, though in 21 hr. the caseinate acquired second place to gelatine as a protective agent for stabilising lead arsenate suspensions.

The suspensions were all neutral to litmus, showing that the free hydroxide had interacted with the arsenate to give soluble sodium arsenate and lead hydroxide, the latter substance probably accounting for the bulky nature of the sediment.

As a protective agent therefore sodium caseinate should be made neutral; 0.1 per cent. caseinate showed a decided advantage as a promoter and stabiliser for the first three hours, probably because of lack of alkalinity.

CALCIUM CASEINATE SOLUTIONS. (*a*) 5 g.m of commercial casein were slowly stirred into 200 c.c. of distilled water containing 1.32 gm. of quicklime and dissolved with the aid of gentle heat. The solution was then made up to 1000 c.c. at 23° 60C. The solution so prepared was alkaline to litmus and was 0.5 per cent. as regards casein; (*b*) process repeated using 3 gm. of casein and 0.792 gm. of quicklime; (*c*) process repeated, using 1 gm. of casein and 0.264 gm. of quicklime.

The 0.5 and 0.3 per cent. solutions were alkaline to litmus; the suspensions were also alkaline. The 0.1 per cent. solution possessed only slight alkalinity.

The suspensions had permanent foams which went solid; these were removed as in the case of the gelatine suspensions.

The 0.5 per cent. solution was also prepared another way: 5 gm. of casein were ground to a thin paste in a mortar with 2.47 gm. of precipitated calcium carbonate and a little water. The paste was then added to 500 c.c. of water and any access of carbonate removed from the solution by centrifuging. The solution was then made up to 1000 c.c. at 23° 60 C., (calcium caseinate B in Tables A, B, and C.).

In both cases the 0.5 per cent. solutions were found to be very good promoters of lead arsenate suspensions (Table B, column 1), ranking next to gelatine. As protective agents they were worse than starch during the first three hours, and failed during the 21 hr. experiment.

GENERAL DISCUSSION OF RESULTS.

Water alone can be ruled out in the case of ordinary lead arsenate preparations containing no admixed protective agent, because it suspends mere traces only of arsenate for very short times.

Soap and sodium caseinate (at least in its more concentrated solutions) are useless because of the interaction of free alkali with lead arsenate, resulting in the formation of soluble arsenate.

Starch and dextrin are quite good promoting and stabilising agents, but a large curdy precipitate results from the use of starch, particularly if the starch solution be prepared in the wrong manner. The economic use of these two substances is also a moot point.

Gelatine and calcium caseinate are the best promoters of lead arsenate suspensions; but whereas gelatine is a very good protective agent, calcium caseinate fails badly in this respect. Gelatine, moreover, possesses marked advantages which are discussed under the heading " gelatine solutions "; at the same time calcium caseinate possesses the *initial* advantage of being soluble in

cold water, thus making preparations of suspensions on the farm easy. Both should be of commercial value, particularly if the calcium caseinate suspensions be occasionally stirred to promote re-suspension. The gelatine will be much cheaper if bought as size, glue, etc.

It will be noticed that with the use of a protective agent the arsenate need not be in paste form as there is no difficulty in wetting it.

THE POSSIBILITIES OF GRINDING.

Grinding of lead arsenate as a means of forming stable suspensions should have great commercial possibilities (4).

The object of grinding is to reduce the particles of the substance as nearly as possible to molecular dimensions, thus conferring great stability on the suspensions when made ; for consider the cases of a true solution such as salt solution, a colloidal or suspensoid solution such as that of sulphur or silver in water, and a suspension such as kaolin or lead arsenate in water ; the true solution and the colloidal solution are stable and permanent, but the suspension deposits its solid particles, particularly if no protective agent be present. This stability is found to depend on the size of the particles held in suspension by the liquid medium. The true solution is homogeneous, its solid particles being of molecular dimensions (about 10^{-8} c.m. radius) ; the colloidal solution and suspension are both heterogeneous, the solid particles being larger than molecules, the radius of a colloid particle being about 10^{-6} c.m., and of a suspension particle about 10^{-3} c.m. The colloid particle approaches so nearly in size to a molecule that it is subjected, as stated by Ramsay (10) and Gouy (11), and later proved by Perrin (12) to a haphazard bombardment by the molecules of the liquid medium; this bombardment keeps the colloidal particle in incessant motion, causing what is known as the " Brownian Movement," and hence stabilising the colloidal solution. The particles of a suspension have a more sluggish Brownian Movement due to the ineffectiveness of the bombardment of comparatively large solid particles by the molecules of the liquid medium ; suspensions are, therefore, much less stable.

P. P. von Weimarn (13) considers that any substance may be obtained in the colloidal state provided the correct conditions prevail ; mechanical grinding, therefore, should be a dispersion process for obtaining colloidal solutions or suspensions from bulk material. On grinding a substance, coarse particles and very fine particles are formed ; but the same grinding action which is tending to sub-divide the coarse particles tends also to make the fine ones coalesce and re-form coarse particles (14). P. P. von Weimarn therefore suggested grinding the substance with an indifferent solid dilution matter which would be soluble in the liquid dispersion medium, the object being to prevent coalescing of the fine particles during grinding. By grinding sulphur with urea in this manner,

N. Pihlblad (15) has succeeded in making colloidal solutions of sulphur in water.

G. Wegelin (16) has prepared colloidal solutions of silicon, antimony, etc., by simply grinding the pure substance with water as the indifferent diluent material. As lead arsenate suspensions for spraying are made up in water, this latter would seem to be the indifferent material for grinding with the arsenate.

Special forms of machinery are now used for fine grinding; no efficient grinding can be done easily in the laboratory, but the use of an ordinary pestle and mortar demonstrated the possibilities of grinding. The following results showed the effect of suspending 2 gm. of the stock sample of lead arsenate (column I), 2 gm. of the lead arsenate ground "dry" for 3 min. in a porcelain mortar (column II), and 2 gm. of lead arsenate ground with 2 c.c. of water for 3 min. in the same mortar (column III), in 100 c.c. of water.

Time (min.).	I. Vol. of Sediment (c.c.).	II. Vol. of Sediment (c.c.).	III. Vol. of Sediment (c.c.).
1	1.75	6.5	25.0
4.5	4.5	5.0	9.25
10	4.5	4.75	6.0
35	5.0	5.0	6.5
	Order of "creaminess" of supernatant liquid →→		

Of course not much of the lead arsenate remains in permanent suspension after the trivial grinding which can be given in a porcelain mortar; but the reluctance of the flocculent sediment to settle after grinding, particularly after grinding with water as a neutral separating substance indicated the possibilities of efficient grinding such as can be carried out in a works. Moreover, as lead arsenate is now sold as a paste with water, no objection can be raised to continuing to sell in paste form.

The use of a protective agent *for preventing sedimentation* would be quite unnecessary if all the particles were reduced in size to about 10^{-3}—10^{-4} c.m. radius; but it is probable that the surface tension of a suspension of lead arsenate in water alone would not be low enough to wet the leaves and cause even spreading of the arsenate, and thus the suspension would drip from the foliage. As soap cannot be used to lower the surface tension to the wetting point because of interaction with the arsenate, it would be necessary to fall back on a protective agent such as calcium caseinate or crude gelatine; for, as mentioned before, protective agents do lower surface tension to a certain extent, and thus cause wetting of, if not great spreading on, the leaves (2).

Moreover they cause retention of a greater volume of the spray fluid by the foliage owing to increased viscosity and adsorption effects (2).

The recommendation seems to be, therefore, to grind the arsenate with an economic amount of water to a finer form than is present in the usual paste form, but not so fine as to make the grinding too expensive, and then to use some protective agent such as 0.2 per cent. (2 lb. per 100 gall.) gelatine or calcium caseinate as much for the purposes of wetting and spreading as for protective action. A permanent creamy suspension of lead arsenate should result, showing no tendency to sedimentation. The protective agent could, with advantage, be ground with the arsenate.

In conclusion the writer wishes to thank R. H. Adie, Esq., M.A., for the kind interest he has taken in the work.

SUMMARY.

Ordinary lead arsenate will not form suspensions with water alone, and hence the use of protective agents is advised.

With a protective agent it is unnecessary to use the paste form of lead arsenate as wetting of the dry arsenate and formation of suspensions is easily accomplished.

The power of various protective agents to form and maintain suspensions of lead arsenate in water has been determined by a rough quantitative method ; it has been shown that readings of the volume of sediment thrown down by such suspensions are not true indexes of the power of these agents to maintain the suspensions.

The protective agents or colloids examined were gelatine, casein (as the calcium and sodium salts), soap, starch and dextrin (or British gum). Gelatine at concentrations of 0.3 per cent is by far the best both for promoting and maintaining the arsenate suspensions Calcium caseinate ensures the making of concentrated suspensions, but these are not lasting suspensions.

Soap is not of much use ; moreover the free alkali (always present in the cheaper commercial forms of hard and soft soaps) interacts with the lead arsenate to form soluble alkaline arsenates, which scorch foliage ; the same thing occurs with the free alkali present in sodium caseinate solutions. In addition soap probably reacts with lead arsenate to form insoluble lead soaps which are liable to clog up the spraying nozzles.

The economic use of starch and dextrin, though both are fairly good protective agents, is a moot point ; starch gives a large flocculent precipitate.

The use of gelatine (or its crude forms, size and glue) and calcium caseinate is advocated ; the suspension in the case of calcium caseinate would have to be occassionally stirred to promote re-suspension. The use of these two substances increases the volume of spray retained by the leaves in spraying because of

increased viscosity and adsorption effects. Gelatine in addition is insoluble in cold water, and when a mixed film of gelatine and arsenate has dried on the leaves the film would not be washed off by rain.

The possibilities of fine grinding of lead arsenate have been discussed. It is quite possible that grinding the arsenate with an indifferent dilution material such as water would reduce the particles to such a fine form as to give a lasting suspension of the arsenate in water alone. Such a suspension, however, because of its high surface tension, would have no tendency to wet and spread on the leaves ; hence the use of some substance to lower surface tension is advocated. As soap cannot be used owing to interaction with the arsenate, the use of some protective agent such as gelatine (size or glue) or calcium caseinate is advised ; this would be used *primarily* in this case to reduce the surface tension of the spray fluid so as to obtain wetting of the foliage.

Finally, for a lasting wetting suspension with no sediment it is advocated to grind lead arsenate with water to a finer state than is present in the normal paste form, and use *as a paste* with gelatine at 0.2 per cent. concentration.

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Table A.

Gm. of Lead Arsenate in Various Fractions:

Protective Agent.	Concentration of Agent (per cent.)	TIME. 10 Min. fraction 450-320 c.c.	fraction 320-190 c.c.	fraction 190-60 c.c.	2 hr. 45 min. fraction 450-300 c.c.	fraction 300-150 c.c.	21 hr. fraction 450-300 c.c.	fraction 300-150c.c.
Water alone	—	0.0078	0.0221	0.0278	0.0006	0.0251	0.0191	0.0090
Soap.	3	—	—	—	0.8847	1.3968	0.4566	0.7069
	2	—	—	—	0.7362	1.2558	0.2499	0.3876
	1	—	—	—	0.0003	0.0738	—0.0237	0.0618
	0.5	0.2956	0.3294	0.3416	—	—	—	—
Dextrin.	0.5	0.9649	1.1846	1.5876	0.1233	0.1458	0.0483	0.0663
	0.3	—	—	—	0.0462	0.0627	0.0132	0.0232
	0.1	—	—	—	—0.0006	0.0084	—0.0066	—0.0066
Starch: (well boiled)	0.5	1.0983	1.1812	1.1893	0.2925	0.6285	—0.0102	0.0870
	0.3	—	—	—	—0.0639	—0.0126	—0.0978	—0.0906
	0.1	—	—	—	0.0138	0.0678	—0.0192	—0.0072
Starch: (not boiled)	0.5	0.0603	0.0728	85 c.c. sediment in fraction.	—	—	—	—
Casein as Na Salt	0.5	0.3635	0.3926	0.4404	0.1689	0.2325	0.0405	0.1092
	0.3	—	—	—	0.0798	0.2445	0.0246	0.0630
	0.1	—	—	—	0.4005	0.5520	—0.0228	0.0120
Casein as Ca Salt (A)	0.5	1.4157	1.6117	1.8060	0.2364	0.5430	—0.1845	—0.0855
	0.3	—	—	—	0.2469	0.4599	—0.1131	—0.0507
	0.1	—	—	—	—0.0225	0.0174	—0.0642	—0.1068
(B)	0.5	1.3684	1.4001	1.7836	0.1320	0.3465	—	—
Gelatine	0.5	1.5044	1.8148	1.8554	0.3945	0.8568	0.1641	0.4680
	0.3	—	—	—	0.5040	0.8841	0.1143	0.3009
	0.1	—	—	—	0.2259	0.4062	0.0288	0.1167

TABLE B.

Amt. of Lead Arsenate in gm. in top 300 c.c. of Suspensions after various times.

Protective Agent Used.	AGE OF SUSPENSION: I. 10 min. Amt. in Suspension. (gm.)	Order.	II. 2 hr. 45 min. Amt. in Suspension. (gm.)	Order.	III. 21 hr. Amt. in Suspension. (gm.)	Order.
Water alone	0.0385	8	0.0257		0.0281	
Gelatine	3.8900	1	1.2513 (32.2%)	1	0.6321 (16.25%)	1
Soap	0.7182	7	—		—	
Starch	2.6350	4	0.9210 (34.2%)	2	0.0768 (2.9%)	4
Na Caseinate	0.8916	6	0.4014 (45.0%)	5	0.1497 (16.8%)	2
Ca Caseinate (A)	3.5834	2	0.7794 (21.7%)	3	—0.2700	5 ?
Ca Caseinate (B)	3.3173	3	0.4785 (14.4%)	4	—	6 ?
Dextrin	2.6350	4	0.2691 (10.2%)	6	0.1146 (4.3%)	3

The figures are for protective agents at 0.5 % concentration.

Columns II. and III. are obtained by adding together the amounts in the two top fractions (see Table A).

Column I. is obtained by adding together the amounts in the two top fractions, plus $\frac{4}{13}$ the amount in the third fraction (Table A); i.e., $130 + 130 + \frac{4}{13}(130) = 300$ c.c.

Column I. is taken in the text to be the promoting power of the agent; columns II. and III. (at much longer times) the stabilising or protective power of the agent. It should be noted that the order of protective power is really the order of percentage of arsenate suspended at any given time of the amount of arsenate initially suspended (10 mins. column); the percentages in brackets correspond to this idea. The sprayer, however is more concerned with the total amount of arsenate suspended at any given time and hence the numbers given under "Order" columns are used in the text. Some theoretical justification can be found for this if it be postulated that at time = 0 min. (when the suspension is just made) the whole of the arsenate is momentarily suspended.

TABLE C.

Concentration of Protective Agent ; %.	10 min. Set.		2 hr. 45 min. Set.		21 hr. Set.		
	5 min.	10 min.	10 min.	2hr. 45 min.	10 min.	2 hr. 45min.	21 hr.
Water alone	52.5	42		41.5		42	41.5
Gelatine 0.5	4 (no clear)	5 (no clear)		12 (10 p.c.)		12 (10 p.c.)	15 (10)
0.3				12.5 (10)		12.5(10)	15(27.5)
0.1				17.5(12)		18(11)	22.5(25)
Soap 3				25		25	48
2				28		28	55
1				45		48	62.5
0.5	44(1.5)	35(1.5)					
Dextrin 0.5		11.5(1.5)		27.5(10)		27.5(10)	31(all clear)
0.3				25(20)		26(20)	30(all clear)
0.1				26(nearly clear)		26(nearly clear)	27(all clear)
Starch : (not boiled) 0.5	165	145					
(well boiled) 0.5	46(2)	44(2)		50(10)		50(10)	50(47.5)
0.3				57(12.5)		57(12.5)	60(100)
0.1				35(30)		32.5(30)	31(135)
Casein as Na Salt 0.5	44(no clear)	40(no clear)	41(no clear)	26(clearing)	41(no clear)	26(clearing)	27(15)
0.3			40(1.5)	26(15)	40(1.5)	26(15)	30(30)
0.1			7(3)	12.5 (15 p.c.)	7(3)	12.5 (15 p.c.)	16(105)
Casein as Ca Salt 0.5 A		14(no clear)	15(no clear)	25(10)	15(no clear)	25(10)	20(100)
0.5 B	7(0.5)	12.5(1)	14(1)	22.5(12.5)	14(1)	22.5(14)	28(all clear)
0.3 A				25(10)		25(10)	27.5(> 100)
0.1 A				26(10)		26(10)	27.5(> 150)

The figures correspond to c.c. of sediment observed at different times.

The figures in brackets refer to c.c. of clearing at the top of the suspension ; "p.c." means "partially clear".

THE PHYSICS OF SPRAY LIQUIDS.

III.—ON THE EASE OF FORMATION OF EMULSIONS.

By ROWLAND MARCUS WOODMAN.

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INTRODUCTION.

THE study of emulsions has great bearing on many important practical problems and is of special interest in horticulture, for paraffin oil emulsions have often been advocated for the destruction of " sucking " insects such as aphides, psylla (apple and pear suckers) and capsid bugs. One direct outcome of this is the now classical paper of S. U. Pickering on emulsions (1).

According to Pickering (2) " undiluted paraffin is considered in this country, and very rightly so, to be too dangerous a substance to apply to fruit trees, even in the dormant season, and even the most carefully selected oil cannot be used, as a rule, on apple-trees in leaf." Now the dilution of paraffin oil is a matter of some difficulty, paraffin oil is insoluble in water, but must, for economic reasons, be diluted with some such cheap and plentiful diluent as water ; for this reason the method of dilution advocated is to make an emulsion of the oil in water.

An emulsion is a system made up of tiny particles of one liquid dispersed or suspended in another immiscible liquid ; the dispersed liquid is called the *disperse* phase or medium, whilst the other liquid constitutes the *dispersion* or *continuous* phase or medium because it extends round the particles of the disperse phase. An emulsion is thus only capable of dilution with the continuous phase liquid.

On shaking a liquid such as an oil with water, the oil is broken up into tiny globules which are dispersed in the water ; on standing, the oil particles rapidly coalesce and rise to the surface as a layer of oil, leaving a *very dilute* emulsion of oil in water underneath ; this emulsion is much too dilute to have insecticidal properties and, in order to make stronger emulsions, it is necessary to make use of some third substance such as soap, gelatine, etc., which is called an emulsifier or emulsification agent.

Pickering (2) has made experiments at Woburn to examine " the action of various emulsions, as well as of undiluted paraffin and other substances, on the mussel scale " eggs. He found that with the fractions of a lighting oil boiling at 165-220° C., 220-285° C., and above 285° C., the mortalities of the eggs were respectively 40, 50 and 99 per cent. " When this same oil was used in the diluted form of an emulsion, the results were, naturally, less satisfactory, and showed no probability of becoming more so until the proportion of oil was raised to about 25 per cent." Thus emulsions with 1 per cent. of soap and 4 per cent. of oil caused no mortality; with 1 per cent. of soap and 15 per cent. of oil only 43 per cent.

mortality. Moreover (2) " to be effective in killing woolly aphis, the emulsion would have to contain 50 per cent. of oil " ; Pickering found such an emulsion did more damage to the trees (in foliage) than undiluted paraffin, and suggests that the soap and water in the emulsion retard the evaporation of the oil, so that it acts on the foliage for a longer time. He arrives at the conclusion, therefore, " that it is better to apply the oil undiluted than diluted in the form of a strong emulsion " ; " a similar conclusion " is " deduced from experiments on the black currant gall mite."

The use of paraffin emulsions can only be advocated for trees in the dormant season, and even then the strong emulsions necessary for effective control of insects and eggs may be prejudicial to the health of the tree ; it is a matter of common experience that dilute emulsions containing so low an amount of oil as one per cent. cannot be used with safety on trees in foliage. Fryer (3) states this scorching effect to be due to the fact that " such emulsions are in practice so liable to separate." Hence we arrive at the " impasse " that a cheap, easily-procurable and excellent insecticide cannot be used even at such small dilutions as one per cent. at the time when the remedy would be most effective, *i.e.*, against the insects themselves, when the buds are opening.

The suggestion of Pickering (2) cannot, the writer thinks, be alone responsible for the failure of such dilute emulsions. Fryer's statement is also rather obscure : he does not explain what he means by the statement that the emulsions are " liable to separate," *e.g.*, he does not explain whether the emulsions actually " crack " or " break " to give free oil, or whether the separation is mere " creaming " of the emulsion.

SCOPE OF PRESENT INVESTIGATIONS.

In view of the above, the writer proposed to ascertain some of the more important causes of the scorching effect of dilute emulsions on foliage and, if possible, obviate this scorching effect. This, and the next paper, are therefore concerned with all phases of emulsions and emulsification, and the random nature of some of the experiments can only be excused by the facts of the writer's previous lack of knowledge of the large amount of emulsion literature and of the experimental technique necessary to deal with this specialised branch of physical chemistry. At the outset the writer, in trying to find an easy, efficient method of preparing emulsions, hit accidentally on the intermittent shaking method ; reference to the literature showed this to have been first noticed by Briggs in 1920 (4).

The experiments revealed many interesting results and indicated causes for the failure of paraffin emulsions in practice ; finally, an alternative method of applying paraffin to trees was found. This method will be discussed fully in future papers, but it may be remarked here that the method may mean that spraying of trees in foliage by dilute paraffin may be possible with average safety.

EFFECT OF INTERMITTENT SHAKING ON EASE OF EMULSIFICATION.

While making preliminary experiments on emulsions with a view to finding the easiest method of formation, 5 c.c. of a 0.4 per cent. solution of Coignet's Gold Leaf gelatine and 5 c.c. of benzene were shaken together continuously in a test-tube for about a minute without emulsification occurring, the benzene rising to the surface as a separate layer ; later, for some reason, the test-tube's contents were given another shake or two, and emulsification at once occurred, as evidenced by the swishing sound heard on emulsification, the increased resistence of the test-tube's contents to further shaking, the appearance of large and fairly permanent air-bubbles entangled near the surface and the non-rising of a benzene layer from the opaque viscous contents of the test-tube.

This was investigated, and it was found that intermittent shaking (*i.e.*, shaking with rests between each shake), was much more effective than long continuous shaking. Thus in one case four shakes at intervals of 30 sec. (by stop-watch) caused emulsification of 5 c.c. of benzene with 5 c.c. of the gelatine solution, whereas a minute's rapid and vigorous shaking did not. By varying the time between the shakes in several experiments, it was found that there existed a minimum time for emulsification.

Reference to the literature showed these facts to have been noticed first by Prof. Briggs (4) for benzene and sodium oleate solution.

It was further found that on plotting the time between the shakes and the number of shakes together, a smooth curve was obtained (Graph I.).

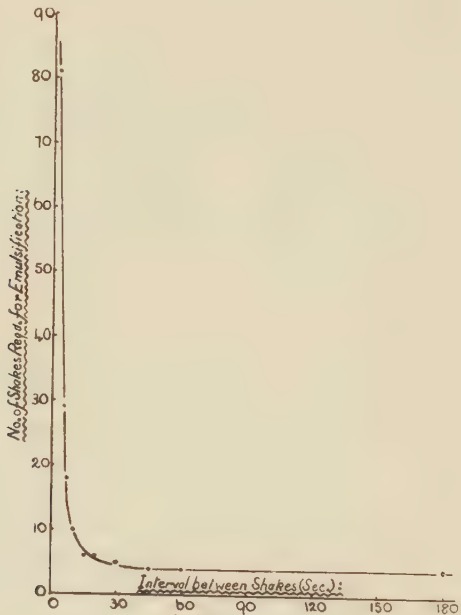
5 c.c. of benzene and 5 c.c. of 0.4 per cent. gelatine solution were shaken together by hand in a test tube, observing a definite time between the shakes (up and down motion of the hand). The time between the shakes was varied in different experiments and, by using the same clean test-tube in every case, comparative results were obtained (Table A, Graph I.) ; by working quickly so that the whole series of experiments took about an hour only, the effects of the ageing of the gelatine solution were made negligible (see later).

TABLE A.

Rest Interval Between Shakes (t). Sec.	No. of Shakes Required (n).	Total Time for Emulsification (=(n–1) t). Sec.
2	81	160
5	29	140
7	18	119
10	10	90
15	6	75
20	6	100
30	5	120
45	4	135
60	4	180
180	4	540

The results show definitely that the interval between the shakes has a great effect on ease of emulsification ; by extrapolation of the graph it will be seen that a large number of rapid shakes would be needed to cause emulsification. Increasing the interval causes the total time for emulsification to decrease to a minimum ; increasing the interval beyond this point has not much effect on the number of shakes, and therefore the total time for emulsification increases.

Briggs (4) advances the explanation that anything tending to break up the future continuous phase will retard emulsification, *i.e.*, that the ideal emulsifying process is one causing the disperse phase to break up into drops



GRAPH I.

with least disintegration of the continuous phase. Discussing the case of benzene and sodium oleate solution, he states that on shaking, the benzene drops are prevented from coalescing by the soap, whilst there is nothing to prevent the rapid coalescence of water drops in benzene ; hence even in uninterrupted shaking some time must elapse before the soap solution is really disintegrated into drops, and during this time it seems reasonable to assume that the benzene would be permanently emulsified in the greatest amount. The first few shakes should therefore be more effective than the subsequent ones. If this be granted, the beneficial action of intermittent shaking follows at

once, for the rest interval allows of coalescence of the continuous phase and each shake is thus a first shake.

Clayton (5) thinks this explanation only partially true ; the smashing forces between the particles become more feeble as the emulsion becomes more perfect, whereas the smashing action should be increased ; continuous shaking should therefore give equally good results as intermittent shaking provided the emulsified portions could be withdrawn continuously, so that the energy of the shaking is concentrated on the remainder.

Granting the assumption that adsorption is a time phenomenon and is not instantaneous, the writer proposes another explanation which would wholly or in part explain the value of intermittent shaking. In the first shake small globules of the disperse phase (and possibly the continuous phase, but these globules coalesce again) are produced, and adsorption of the emulsifying agent begins at the liquid—liquid interface of the two phases ; a rest interval now allows adsorption to become well-established, the excess of disperse phase rising as a layer to the surface. Another shake now breaks up some more of the disperse phase, adsorption commencing on the new globules ; at the same time the old globules are probably cleaved into smaller ones, adsorption beginning on the new cleavage surfaces. Repetition of this intermittent shaking allows of easy emulsification, the utmost value being derived from each shake. Continuous shaking, however, means disturbance of the adsorption layer practically as soon as formed, adsorption thus being well-established very slowly. The existence of a minimum time for emulsification when using intermittent shaking thus means that the rest period allowed between the shakes is that necessary for adsorption to become firmly established.

EFFECT OF INCREASE IN VOLUME OF FUTURE DISPERSE PHASE ON EASE OF EMULSIFICATION.

Intermittent shaking is not the only contributor to ease of emulsification ; Pickering's emulsion of ninety-nine per cent. of oil in 1 c.c. of a one per cent. solution of soap was made by adding the oil in small amounts to the continuous phase and emulsifying between each addition (1) ; Briggs (4) has shown also that concentrated emulsions are best made according to the method employed in making mayonnaise, viz., to build up the emulsion gradually by small additions of oil, emulsifying between each addition. Thus in making some emulsions of about eighty-five per cent. of oil used in experiments described in the next paper, a fifty per cent. emulsion was first made by intermittent shaking (about four thirty second shakes) and the remaining oil was added in 5 c.c. lots, one shake between each addition being sufficient to emulsify. The labour entailed in making an eighty-five per cent. emulsion of oil in water would be enormous

if the oil were added in mass, even if intermittent shaking were resorted to. It is, indeed, a matter of experience that the greater the ratio of disperse to continuous phase, the greater the difficulty in making the emulsion.

EFFECT OF TEMPERATURE ON EASE OF EMULSIFICATION.

Pickering has remarked (1), and it is a matter of experience among sprayers, that the formation of emulsions is favoured by a high temperature.

The effect of temperature was tested: a range of thermostats was prepared varying in temperature from 20°C. to 60°C., and emulsions of the same concentration (66.6 per cent. of oil) were made in these in the same cylinder by intermittent shaking, allowing 30 sec. between the shakes.

The method of procedure was as follows: toluene and the emulsifying agent (0.4 per cent. sodium oleate solution) were kept in bottles immersed to the neck in the thermostats; the cylinder was placed in a thermostat and 10 c.c. of the soap solution pipetted in, followed by 20 c.c. of toluene (the oil used) which was so added as not to disturb the soap solution. After standing in the thermostat a few minutes the cylinder was stoppered, rapidly withdrawn and given a complete shake (up and down of the hand), and then replaced in the thermostat. The cylinder was withdrawn at the end of every 30 sec. and given a shake, the time the cylinder was out of the thermostat being 2-3 sec. in every 30 sec. The occurrence of emulsification was told by the characteristic swish of the liquid, and the appearance of the semi-permanent air-bubbles near the surface. The results are given in Table B.

TABLE B.

Temp. of Thermostat (°C.).	No. of 30 sec. Shakes.
20.75	145
30.75	114
41.30	50
51.00	12
60.50	5

It will be seen that the formation of emulsions is greatly facilitated by an increased temperature.

EFFECT OF AGE OF GELATINE SOLUTION ON EASE OF EMULSIFICATION OF TOLUENE.

In this investigation the effects of the ageing of solutions of commercial and pure gelatine on the ease of formation of emulsions was studied.

A 0.4 per cent. solution of Coignet's Gold Leaf Gelatine was prepared, the amount of gelatine used being corrected for ash and water content; a 0.4 per cent. solution of pure gelatine was also made, the gelatine being purified by Loeb's process (6).

The two solutions were kept in a thermostat at 15°C.; at different times the viscosities of the solutions and the number of intermittent 30 sec. shakes necessary to prepare an emulsion of 20 c.c. of toluene in 10 c.c. of the solutions were found, the latter measurements being made always in the same stoppered cylinder.

TABLE C.

Age of Solutions. (hr.)	Pure Gelatine. Time of Flow Relative to Water=1.	Pure Gelatine. No. of Shakes.	Commercial Gelatine. Time of Flow Relative to Water=1.	Commercial Gelatine. No. of Shakes.	Remarks.
0	1.3	7	1.2	7	transparent
19	4.9	13	5.8	13	,,
27	6.1	18	6.2	17	,,
44	6.6	21	7.2	18	turbid—putrid smell
72	6.6	21	6.5	17	,, ,,
92	6.7	21	4.0	15	,, ,,
140	6.7	21	1.7	13	,, ,,
260	6.8	21	1.0	15	,, ,,

(N.B.—The pure gelatine solution was opalescent-blue throughout.)

From the results in Table C it will be seen that the viscosities of the solutions tend to a maximum, and that this maximum takes longer to attain than twenty-four hours, as stated by Davis, Oakes and Brown (7). As the viscosities increase, the number of shakes necessary to form the selected standard emulsion increases, so that increase in viscosity of the continuous phase tends to make emulsification more difficult.

The viscosity, and the number of shakes required to make the standard emulsion, fell in the case of the commercial gelatine ; the fall was found to coincide roughly with the appearance of a putrid smell in the gelatine solution due to bacterial action ; this of course tends to lower the concentration of the gelatine, and though the viscosity fell in time to that of water the number of shakes did not fall to the initial value because of this lowered concentration.

The viscosity, and number of shakes, did not decrease with age of the pure gelatine after attaining maxima ; correlated with this behaviour was the fact that no evidence of putrefaction could be detected in the solution ; indeed a 0.4 per cent. solution of pure galatine kept in the open till it dried to a horny mass showed no signs of bacterial action. Mr. F. C. Thompson, of the Leather Laboratory, Leeds University, who has noted a like behaviour with his pure gelatine solutions, attributes the lack of bacterial activity to the very low ash content of pure gelatine.

EFFECT OF INCREASING THE CONCENTRATION OF THE EMULSIFIER ON EASE OF EMULSIFICATION ; EFFECTS OF DIFFERENT EMULSIFIERS AND MIXTURES OF EMULSIFIERS.

From what has been stated previously it will be seen that increase of the volume of future continuous phase is conducive to easy emulsification, for this is the same as reduction in the volume of future disperse phase.

It remains to be seen what effect altering the concentration of the emulsifier has on emulsification ; this investigation was worked in with others which might seem to bear promise.

In the first place solutions of 0.4 per cent. sodium and potassium oleates were prepared, the soaps having previously been dried at 100° C. An emulsion was made in both cases (in the same cylinder) containing 10 c.c. of the aqueous solution and 10 c.c. of toluene by the method of intermittent shaking, allowing ten seconds between each shake. In the case of sodium oleate twelve shakes were necessary and in that of potassium oleate two shakes only, proving that for toluene emulsions potash soaps are better than sodium soaps, as Pickering found to be the case (qualitatively) with paraffin emulsions.

On replacing the toluene with paraffin oil two shakes only were necessary in both cases, though one shake was practically sufficient in the case of the potash soap.

The comparison of mixtures of emulsifiers was carried out as follows : 0.4 per cent. solutions as regards pure gelatine and sodium oleate were made up, the gelatine solution being allowed to stand until it attained maximum viscosity ; 0.3, 0.2 and 0.1 per cent. solutions of pure gelatine and soap, and also mixtures of the two containing 0.3 per cent. of gelatine and 0.1 per cent. of soap, 0.2 per cent. of gelatine and 0.2 per cent. of soap and 0.1 per cent. of gelatine and 0.3 per cent. of soap (the total concentration being always 0.4 per cent. of mixed emulsifiers) were made from the first two solutions as occasion demanded. A standard emulsion was made in all cases, consisting of 20 c.c. of disperse phase (toluene) and 10 c.c. of the aqueous continuous phase ; the number of intermittent shakes at periods of 15 secs. to give complete emulsification was counted in each case ; the results are given in Table D.

TABLE D.

% Gelatine.	No. of Shakes.	Concn. of Mixture } 0.4%	No. of Shakes.	% Sodium Oleate.	No. of Shakes.
		Gel. + Soap.			
0.4	21	0.4 + 0.0	21	0.0	∞
0.3	23	0.3 + 0.1	344	0.1	?
0.2	29	0.2 + 0.2	475	0.2	348
0.1	>500	0.1 + 0.3	270	0.3	223
0.0	∞	0.0 + 0.4	145	0.4	145

(N.B.—In these shaking experiments *vigour* of shake was found to have little effect on the total number of shakes for emulsification.)

It was noticed that those emulsions made with soap were much finer-grained than those made with gelatine, the explanation probably being that due to Pickering (8) that the size of emulsion particles varies directly with the size of the particles of the emulsifying agent ; or probably the low surface tension of soap solutions has this effect.

The results show that gelatine is a much better emulsifier for toluene emulsions than sodium soap ; the viscosity of the gelatine solution was fairly

high (see previous results) and that of soap solutions at the dilution used practically the same as for water (9) ; the surface tensions of soap solutions stronger than 0.1 per cent. are also very low (9) ; yet despite these facts, apparently in favour of soap as an emulsifier, the gelatine was superior at the dilutions used. Probably the explanation of this is that the gelatine is adsorbed much better than sodium oleate, being probably more colloidal in nature.

Table D shows that increasing the concentration of the emulsifier (within the limits 0.1 per cent. to 0.4 per cent.) facilitates the formation of emulsions.

The results for mixtures of gelatine and soap, keeping the total concentration 0.4 per cent., do not yield much information. In all cases the mixtures are not such capable emulsifiers as solutions of gelatine or soap alone at 0.4 and 0.3 per cent. concentration. The 0.3 per cent. gelatine plus 0.1 per cent. sodium oleate mixture was noticed to be very viscous and mucilaginous. The curve of number of shakes against composition of mixture showed a maximum at 0.2 per cent. gelatine plus 0.2 per cent. soap.

SUMMARY.

Emulsions of oil in water, especially if concentrated, are best made by using the method of intermittent shaking first described by Briggs (4) ; a new adsorption theory of the advantages of intermittent shaking is given in the text. The method is utilised to give a comparative idea of the ease of formation of emulsions.

Oil emulsions are much easier to make at high temperatures, and by adding the oil phase gradually and emulsifying between each addition.

High viscosity of the aqueous continuous phase has an adverse effect on ease of emulsification ; low surface tension of the continuous phase does not seem to be very beneficial.

Gelatine and potash soaps are much better emulsifiers than sodium soaps.

Mixtures of emulsifiers such as gelatine and soap do not cause easier emulsification.

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EGG-KILLING WASHES.

By A. H. LEES, M.A., *Long Ashton*.

WINTER spraying of fruit trees has been a text-book recommendation for a very large number of years, and the advice to do this operation has been given over and over again by those whose business it has been to advise the grower. It may be questioned, however, whether in most cases the giver of the advice had a clear idea of how any particular winter spray fluid worked. In most cases the cleansing of the trunks was emphasised and frequently claims for killing insect eggs were made. No one had, however, so far as the writer is aware, produced any proof of egg-killing powers of any winter wash at that time.

In 1914 the writer referred to the then position of winter spray fluids (1) and certain mixtures were tried which, however, were not successful.

In 1915 (2) further trials were made which showed that hot water was unpracticable, but that with certain bleaching powder treatments some success was obtained.

In 1917 and 1919 Peterson (3 and 4) working in U.S.A., published papers showing the effect of various sulphur washes and of crude carbolic acid on the eggs of apple aphids. He found that the higher concentrations of lime sulphur 1 in 6 and 1 in 9 gave good kills, and he obtained promising results from the use of crude carbolic acid.

The results with lime sulphur appeared to warrant further trials of this substance in this country and various small trials were done by the writer using this substance. It was very soon evident, however, that sufficiently exact data could not be obtained by any field trial and accordingly the method of trial on eggs of Aphis pomi on pot trees was started. Conditions could thus be much more effectively controlled while the eggs were still under an outside environment until hatching started. A few months before this conclusion was reached Mr. S. P. Wiltshire, at that time Mycologist to the Research Station, brought back from Holland, during the summer of 1921, samples of a Dutch " Carbolineum " which has been giving consistently good results in that country. It was accordingly included in the 1921 trials, the results of which encouraged its introduction as a commercial article the following year. More recently several British forms of the tar distillate washes have appeared.

The following paper describes the results in the third season of testing egg-killing washes. Especial attention has been paid to the tar-distillate washes frequently sold with the prefix " carbo." An attempt has been made to form fluids with Cresylic Acid, a substance which in last year's trials gave excellent results. In addition further tests have been made on Lime-Sulphur with a view of possibly confirming previous years' results.

PROCEDURE.

The eggs selected as a test were again those of the Permanent Apple Aphis. This is the only insect egg that can be obtained in sufficient quantity on a limited space. No other aphis eggs are suitable, as they are always laid in an isolated manner instead of in masses. Apple sucker and caterpillar eggs have a similar disadvantage.

I am much indebted to a well-known nurseryman for obtaining for me apple plants well infested with eggs in a year in which such material was very difficult to find. These plants were ungrafted stocks of Malling Paradise types 2 (Doucin) and 5 (Improved Doucin). As was to be expected, the type 2 specimens were considerably stronger than the type 5.

When received the plants were potted up in ordinary potting soil and placed outside. At various times during the winter spray fluids were applied by means of a small hand-spraying machine. This work was done in a cold and airy greenhouse. The plants were allowed to dry and then placed outside exposed to all weather conditions. Shortly before hatching began they were taken under cover and placed horizontally over oiled paper. Most of the young lice fall off under these conditions and are thus easily counted. Those that remained on the plant (as happens when a bud is showing green) were removed and counted. After hatching had finished the plants were cut into convenient lengths and submitted to hot 10 per cent. caustic soda for a short time.

This treatment loosened the eggs, which were then carefully washed into another vessel and made up to 1,000 cc. Aliquot portions of the agitated liquid were poured on to a petri dish and the contained eggs counted. The average of six countings gave the number of eggs present. A simple calculation from this gave the total estimated number of eggs on the particular plants.

CONTROLS.

Table 1 gives details of the controls. There were eight of Type 5 and five of Type 2. The lowest percentage hatch for Type 5 was 4.3, the highest 16.1 and the average 10.6. The lowest for Type 2 was 15.6, the highest 85.1, and the average 49.7. It is clear from these figures that the eggs on Type 2 were more viable. It is also clear from a consideration of the number of eggs present in each case that this number had nothing to do with the percentage hatch. Further evidence that the type influenced the percentage hatch is found in Tables 2-5. In these, where a strict comparison of treatments could be made, the average for the two types is shown.

Thus in Table II,	Type	5	gave a	percentage hatch	of	3.88,	Type	2	of	33.4
III	,,	5	,,	,,	,,	1.03,	,,	2	,,	6.63
IV	,,	5	,,	,,	,,	11.6,	,,	2	,,	24.6
V	,,	5	,,	,,	,,	13.0,	,,	2	,,	19.4

Only in one case, A In Table III, does Type 5 give a higher figure, 2.95, over Type 2, with 1.03. It would appear therefore from five different series that the eggs on Type 2 were more viable than those on Type 5.

It has been pointed out previously that there is no correlation between the number of eggs used and the percentage hatch on the controls, and this same absence of correlation can be seen in Tables II-V. There would appear, therefore, to be only one conclusion, namely that the stronger stock offered more food to the egg-laying female than the weaker, and that in consequence her eggs were more viable. This conclusion introduces a factor previously overlooked in egg-killing trials, and serves to explain some of the discrepancies in the controls observed in previous years. It serves also to emphasise the writer's previous contention that unless an egg-killing wash gives a percentage of hatch of about one, it it is not likely to be very effective in practice.

Lime Sulphur.

This fluid gave very encouraging results in the previous year's trials, especially when combined with a spreader. In order to obtain confirmation they were repeated in this year's trials. Three strengths were tried, one volume of concentrate in 15 volumes, one in twenty, and one in thirty. In one series these were combined with .1 per cent calcium caseinate (1 lb. per 100 gallons) as a spreader ; in the other the lime sulphur was applied alone, and each series was done twice, once in December and once in February. Table II contains the results. An inspection of the percentage hatch figures clearly shows that no effective egg-killing has been obtained except the 1/15 with caseinate done in December. This figure, however, is not supported by those for the other strengths (6.6, 7.7). No improvement can be seen as the result of adding caseinate either in December or February. The figures for the December spraying are on the average very much lower than those for the February spraying, but it would seem easier to attribute this to the influence of the weaker stocks (as shown by the controls) than to the time of application. Lime sulphur made up with .1 per cent. "soluble casein," a proprietory spreader with improved properties, also failed to show definite egg-killing powers.

The difference between the results obtained last season and this as regards lime sulphur are surprising and to the writer unaccountable. It is evident, however, that for the present lime sulphur must be regarded as an unreliable egg-killing wash and in view of the continued success from tar distillate washes it would be advisable to discontinue its use against insect eggs during the winter except in special instances.

TABLE I.

Controls.

Stock.	No. of Eggs Estimated.	Percentage Hatch.
Malling Paradise Type V.	1200	7.5
	1150	16.1
	560	13.2
	693	15.2
	420	5.5
	446	13.0
	646	9.9
	2300	4.3
Average for Type V.		10.6
Type II.	320	15.6
	773	48.8
	983	48.1
	660	85.1
	480	50.9
Average for Type II.		49.7

TABLE II.

Lime-Sulphur.

Stock.	Date of Application.	Strength.	With .1% Ca. Caseinate.	No. of Eggs Estimated.	Percentage Hatch.
V.	Dec. 21	1/15	Yes	1193	.92
V.	,,	1/20	,,	560	6.6
V.	,,	1/30	,,	700	7.7
V.	,,	1/15	No	793	3.3
V.	,,	1/20	,,	700	3.4
V.	,,	1/30	,,	662	2.3
Average Type V.					3.88
II.	Feb. 29	1/15	Yes	1283	25.9
II.	,,	1/20	,,	1733	35.4
II.	,,	1/30	,,	1380	29.5
II.	,,	1/15	No	480	25.9
II.	,,	1/20	,,	1733	53.4
II.	,,	1/30	,,	1933	30.2
Average Type II.					33.4
II.	Mar. 4	1/20	1% Sol. Casein.	1516	14.0
II.	,,	1/30	,, ,,	1200	20.7

Tar Distillate Washes.

Since the trials of last year several new washes of British manufacture have appeared on the market. Though these washes are all of a proprietory nature, it was thought desirable to obtain some information as to their efficacy as egg-killers. The information does not admit of publication under specific names, and accordingly they have been assigned letters. The trials have, however, been fully justified, partly on the score of the many enquiries

Table III.

Tar Distillates.

Stock.	Spray.	Date of Application.	Strength.	No. of Eggs Estimated.	Percentage Hatch.
V.	B.	Dec. 21	10%	1086	0.0
V.	B.	,,	5%	733	·4
V.	B.	,,	2½%	520	1.7
V.	B.	,,	1%	906	2.0
Average Type V.	B.				1.03
II.	B.	Feb. 20	10%	3300	.6
II.	B.	,,	5%	1080	2.98
II.	B.	,,	2½%	1233	9·5
II.	B.	,,	1%	2416	13·5
Average Type II.	B.	Feb. 20			6.63
V.	A. (Old)	Dec. 21	4%	340	3·0
V.	A. (Fresh)	,,	4%	1086	3·9
V.	A. ,,	,,	2%	253	2.0
Average Type V.	A. (Fresh)				2.95
II.	A. (Fresh)	Feb. 11	4%	746	.67
II.	A. ,,	,,	2%	4700	1.4
Average Type II.	A. (Fresh)	Feb. 11			1.03
V.	C.	Jan. 8	10%	2100	0.0
V.	C.	,,	5%	1080	·55
V.	C.	,,	2½%	1500	3.0
V.	C.	,,	1%	70	27.0
II.	D.	Jan. 17	10%	2116	.14
II.	D.	,,	5%	4066	1.2
II.	D.	,,	2½%	880	2.4
II.	D.	,,	1%	1243	12.7
II.	E.	Feb. 20	10%	3066	6.1
II.	E.	,,	5%	1120	22.0
II.	E.	,,	2½%	1000	27.2
II.	E.	,,	1%	3616	39·5

TABLE IV.

Cresylic Acid Mixtures.

Stock.	Mixture.	Percentage Cresylic.	Date of Application.	No of Eggs Estimated.	Percentage Hatch.
V.	Cresylic, soap	8%	Dec. 22	516	14.9
V.	,, ,,	4%	,,	1016	7.2
V.	,, ,,	2%	,,	1086	10.5
V.	,, ,,	1%	,,	870	10.7
V.	Cres. soap, casein	8%	,,	980	3.2
V.	,, ,, ,,	4%	,,	640	6.1
V.	,, ,, ,,	2%	,,	1086	33.5
V.	,, ,, ,,	1%	,,	713	6.9
Average Type V.					11.6
II.	Cresylic soap	8%	Feb. 11	—	16.1
II.	,, ,,	4%	,,	1633	8.6
II.	,, ,,	2%	,,	2266	25.2
II.	,, ,,	1%	,,	276	7.2
II.	Cres. soap, casein	8%	,,	3666	22.1
II.	,, ,, ,,	4%	,,	460	47.4
II.	,, ,, ,,	2%	,,	563	35.3
II.	,, ,, ,,	1%	,,	1766	32.5
Average Type II.					24.6
V.	Cres. soap, Red Oil	4%	Dec. 22	633	6.0
V.	,, ,, ,,	3%	,,	460	2.4
V.	,, ,, ,,	2%	,,	1150	3.4
V.	,, ,, ,,	1.3%	,,	320	5.0
II.	,, ,, ,,	4%	Feb. 11	270	34.8
II.	,, ,, ,,	2.6%	,,	1366	7.1
II.	,, ,, ,,	1.2%	,,	1283	76.0

subsequently answered as to their action, and partly because they have shown that not every such material, though indistinguishable by the eye, has definite egg-killing properties.

In Table III will be found the results of these trials. They were designed to test the effect of different strengths and times of application and also of the different brands. In one case the effect of fresh material was tried against material kept for two years in the laboratory in a half-empty but stoppered bottle.

As regards the effect of strengths it is noticeable that in every case, with the exception of A tried in December, the higher strength gave a less percentage hatch than the lower. The divergence in this exception is not marked, and the method may therefore be considered a reliable one and sufficiently accurate to give the difference produced by a 2 per cent. difference in strength. The writer claims that no such accuracy can be obtained by field trials.

Summary and Conclusions.

1. This paper describes the results obtained by the application of certain spray fluids on the eggs of Aphis Pomi. the Permanent Apple Aphis.

2. Both in the controls and in every other comparable case the eggs laid on Malling Type II, stocks proved more viable than those on Malling Type V.

3. Lime Sulphur at all strengths tried with or without calcium caseinate failed to show definite egg-killing power.

3. Tar Distillate washes gave generally good results and the method of testing is accurate enough to show the effect of a difference in strength of wash applied of 2 per cent.

5. It was not possible to state whether early or late applications of Tar Distillate washes is the more effective, owing to the apparent difference of viability of eggs in the two series.

6. Commercial Cresylic Acid, whether made up with soap as a wet spray or with dry carriers as a dust, failed to show egg-killing power.

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APPLE PACKING STATION: PROGRESS IN ENGLAND.

By H. V. TAYLOR, A.R.C.S., B.Sc., M.B.E.

The grading and packing of apples has been much debated in this country during the past four or five years, and some progress has been made in applying the systems in marketing home-grown apples. Some growers with large acreages of fruit have been able to train and retain expert packers, and to equip their home packing sheds with the necessary machinery to perform the various operations with ease and rapidity; but the smaller men have found it more difficult and a number have come to the conclusion that the grading and packing movement must develop but slowly in this country unless groups of growers combine together to establish packing stations for the use of all. This of course expresses exactly the past experiences of fruit growers in the United States of America and Canada: though as their fruit had to be transported over longer distances the need for packing stations was greater. The story has not been told of the way in which the growers in those countries have combined to establish apple packing stations, but it is known that in all the fruit districts of Canada and America there have sprung up apple packing stations through which practically all the North American fruit passes before being marketed. Some of these stations are owned by commercial firms, others belong to groups of growers and a third class would truly fall into the category of co-operative packing stations.

Which category predominates or which gives the best results it would be difficult to determine, but from information supplied by the Departments of Agriculture for both Canada and the United States of America there can be no doubt that a very large number of these packing stations are in existence. Each station packs in accordance with the State rules and regulations and the packages are marked with distinctive labels identifying the brand. Some of these brands of apples have gained great popularity in the sale rooms in British markets and the results of this system are apparent to all familiar with fruit markets in this country. Why similar stations have not been erected in this country, either by merchants, groups of growers, branches of the National Farmers Union, or the Federation of British Growers, is not clear, for it seems just the kind of work that would prove useful. Fortunately some progress has been made in England this year in two counties.

A commercial company trading as the British Fruit Packing Co., Ltd., has established in some farm buildings near Yalding Station, Kent, an apple packing station, equipped with the most modern machinery, and provided with suitable storage accommodation. This station is being managed by a Mr. Gregson, who has had experience of the working of the large apple packing station of the Associated Growers of British Columbia. This Kent station is favourably situated in the midst of a very large fruit area, and is capable of handling daily a large quantity of fruit. Besides grading and packing the apples, it is understood that the company undertakes the transport of the fruit by road to London Markets. Such, then, is the beginning of the movement in Kent.

Progress in another district is due to the action of the members of the West Cambridge Fruit Growers Association, of which Sir Douglas Newton is the president. At a meeting of this Association held in Cambridge on 8th March, 1924, it was resolved " that the Association . . . would be willing to arrange for the supply of apples, pay the Ministry an agreed charge per package for packing house expenses, and be responsible for the business management of the station (including the sale of fruit, receiving and paying out to members the proceeds of sale, after deducting expenses), and would be glad to know whether the Ministry would undertake the responsibility for the grading and packing of the fruit (including the hire of building, purchase of machinery, equipment and packages, and the employment of labour)."

The Ministry was pleased to accede to this request, and, with the consent of the Treasury and the Development Commissioners to the expenditure involved, has rented a building at Cottenham, near Cambridge, equipped it with a large Cutler Grader, box press, conveyors, and other necessary machinery, and engaged and trained sufficient staff to pack this year's small crop. All charges for the hiring and equipment of the station and all working expenses will fall upon the Ministry, but charges will be made for work done at the following rates :—

(*a*) For grading and packing (exclusive of materials used) : 5d. per bushel (40 lbs.), delivered at the Station.

(*b*) For materials used, British Standard boxes, paper, labels, etc. : 1s. each.

(*c*) For paper, packing, etc., where the apples are packed in salesman's empties, or containers supplied by the grower or association : 1d. per half bushel and bushel packed ; 1½d. per half barrel and barrel.

It has been arranged that both these stations will adhere to the following standards for grades :—

SIZE AND COLOUR MINIMUMS FOR APPLES.

Variety.	Extra Fancy.		Fancy and Best (bushel).	
	Colour %.	Size (ins.).	Colour %.	Size (ins.).
Beauty of Bath ..	25	2¼	10	2
Mr. Gladstone ..	25	2¼	10	2
James Grieve ..	20	2½	5	2
Hunt's Early.. ..	30	2½	10	2
Benn's Red	50	2½	10	2
Dev. Quarenden ..	50	2¼	10	2
Lady Sudeley ..	25	2½	5	2
Worcester Pearmain	40	2¼	10	2
Rival	25	2¼	10	2
Charles Ross	25	2¼	5	2
Allington Pippin ..	20	2¼	5	2
Blenheim Orange ..	20	2½	5	2
Cox's Orange Pippin..	20	2¼	5	2
King Pippin	20	2¼	5	2
Early Victoria ..	0	3	0	2¼
Grenadier	0	3	0	2¼
Stirling Castle ..	0	3	0	2¼
Warner's King ..	0	3	0	2¼
Bismark (coloured)	35	3	0	2¼
,, (green) ..	0	3	0	2¼
Lane's (coloured) ..	15	3	0	2¼
,, (green) ..	0	3	0	2¼
Lord Derby	0	3	0	2¼
Bramley (coloured)	25	3	0	2¼
,, (green) ..	0	3	0	2¼
Newton Wonder (coloured)	25	3	0	2¼
Wellington	0	2½	0	2¼
Annie Elizabeth ..	25	3	0	2¼

Standards dessert minimum of 2 in. for box packing.
Standard culinary minimum of 2¼ in. for box packing.

Careful records of the fruit dealt with at the Cottenham station will be kept and it is hoped that as a result of the year's working figures of interest may be obtained. During all the stages the fruit will remain the property of the growers ; it will be delivered by them to the station and sold in bulk by their selected representatives when packed.

Unfortunately the Cambridge crop this year is less than one-third of the average production and limited almost to cooking varieties, so that the station

must start at a big disadvantage. It is, however, to be used during the three weeks September 29th to October 18th, for educational purposes, to give demonstrations in grading and packing to County Instructors and others and to show the working of apple packing stations.

It would be unwise to predict the possible results of the year's working of these two ventures, the one in Kent by private enterprise, and the other in Cambridge by State aid, but it is certain that important pioneer work is being done and the first steps to progress with British apple packing stations recorded.

EXPERIMENTS ON THE MANURING OF FRUIT TREES.—I.

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Modern fruit growing, both in this country and abroad, has of recent years become a very specialised pursuit. Our growers of to-day are faced with very keen competition from overseas and if they are to hold their present markets it will be necessary for them in the future to produce high grade produce at competitive prices. To do this it will be essential for the grower of the future to equip himself with a knowledge of the scientific principles underlying the production of fruit and to base his plantation and orchard practice on these.

The establishing of a modern plantation involves a large capital expenditure and to obtain bulk samples of fruit from these of the high quality desired by the consuming public, the costs of production are of necessity very high. Hence it is of great importance that the various factors contributing to the costs of production should be closely investigated in order to determine how far the various items of expenditure are necessary or profitable.

A matter of great importance in this respect is that of the manuring of fruit plantations. Large sums of money are spent annually by growers on manures, but it is not at present known whether this expenditure is to any extent justified. It cannot be said that the present-day systems of manuring in this country are in any way based on scientific data collected from past experiments on fruit trees as it will be shown in a later section of this paper that these previous experiments have not yielded results from which systems of manuring can be recommended.

That there is great diversity of opinion among growers on the question of the manuring of fruit plantations becomes obvious when the opinions on the question of a number of growers are asked, whilst it is not an uncommon occurrence to find growers completely discarding their practices of manuring and trying others because of their becoming convinced that the old system was not producing results to justify the expenditure.

The acuteness of the position becomes even more emphasised when the wide differences in practice of various growers are compared. In the case of apple plantations especially these vary from systems of heavy manuring to those in which manures are absolutely withheld, and yet when the crops resulting from such widely differing systems are compared these are quite frequently very similar.

Where regular manuring is practised the systems are generally based more or less on the knowledge gained from agricultural experiments, and on such old slogans as " Nitrogen produces growth, phosphates fruit and potash quality and colour."

Fruit growers are generally in a much more unfavourable position than agriculturalists from the point of view of supplies of manure, as many growers do not keep any considerable quantity of stock and hence quantities of farmyard manure are not available except at very considerable expense. The grower who wishes to use manures is thus almost wholly dependent on the so-called " artificials " as his source of supply and it is a well-established fact that in order to obtain the best results from these, even on agricultural crops, considerable knowledge and skill in their use is required.

The question as to whether the best results are obtained from the use of the so-called organic manures, e.g., fish manure, meat meal, hoof and horn, etc., or from the "inorganics," e.g., nitrate of soda, superphosphate, etc., is also one which is constantly being brought up for discussion, most growers favouring the " organics." A further debated point is that of the time of applying manures for fruit production.

These are briefly some of the principal points with regard to the present-day and future situation of the problem of the manuring of fruit plantations as they affect the grower.

It will be the object of this paper to bring to the notice of those interested in this problem the present state of our knowledge of the subject as gained from previous experiments on the subject and to describe the methods we are adopting at this Research Station to extend this knowledge and to put on record some results which we have obtained in our experiments during the seasons 1921-1924.

No attempt is made in this paper to discuss at length the various scientific aspects of the results or the bearing of certain of these on current manurial practice as such discussions would have added greatly to the length of the communication. The discussion of such points will form the subjects of subsequent communications.

Further, it is recognised that the results obtained have opened out several very important lines of investigation and many of these are being followed by the writer in conjunction with the Plant Physiologist of this Station.

The Problem in the Field.

It will be quite obvious to anyone who has given any thought to the problem of manuring fruit trees that the problem as it presents itself in the field cannot be considered without reference to other factors affecting the nutrition of fruit trees, such as soil, climate, stock influence, habits of varieties, cultivation, pruning and spraying practice, etc.

Most growers recognise that such factors are of the very greatest importance in determining their ultimate results, but it is not always realised that certain conditions, cultural operations or practices, produce practically identical results or entirely opposite effects as do certain manurial practices. Nor has this latter point always been sufficiently well recognised by experimenters in interpreting experimental results in the past. The point has been strongly emphasised of late in America by Alderman (1) and Anthony (4) in summarising the results obtained in experiments in the United States.

Except in extreme cases, the effects which are produced by manures on tree fruits, although they may be quite significant, are often not very obvious, as they generally become apparent in a very gradual manner and it is only when the conditions of treated and untreated trees are compared at intervals of three or four seasons that the magnitude of the change becomes evident.

In view of these facts, it follows that experiments in the field will never meet with success unless detailed consideration is given to the various factors influencing the problem, both in the laying out and conducting of such experiments and in interpreting the results obtained in them.

Historical.

In this section it is proposed to discuss briefly the results which have been obtained in past experiments on the manuring of fruit trees, bushes and plants in this country and in America, as these will serve to furnish typical examples of such experiments and to show the state of our present knowledge.

Past experiments which are on record have been almost entirely carried out in the field and have generally been modelled on agricultural experiments of the type first laid down by Lawes and Gilbert at Rothamsted. The various investigators have endeavoured to compare the results produced on the growth and fruiting of trees, etc., by farmyard manure, "complete" fertilisers and fertilisers from which one or more of the essential elements of plant food have been omitted, with results obtained on check plots receiving no manure. In other experiments the use of green crops for manuring purposes and the use of bulky moisture-holding manures as against the use of non-bulky fertilising materials, have been tested. Some typical results of such experiments are given below.

Experiments in England.

In England, the number of experiments carried out has been very few, and of these, the best known are those of Bedford and Pickering at Woburn (6), Dyer and Shrivell at Hadlow (10), Hodsoll and Bickham at Ledbury (15), and Hatton at East Malling (13).

Of these, those at Woburn and Hadlow were by far the most extensive, and the results of the former have been widely discussed by fruit growers in this country.

Woburn Experiments.

The experiments at Woburn were carried out over a period of twenty-two years on apples, bush fruits and strawberries on two widely differing soil types —a heavy clay soil at Ridgmont and a light sandy soil, deficient in potash, at Milbrook.

At Ridgmont, seemingly very curious results were obtained. On apple trees, both dung at 30 tons and 10 tons per acre and " complete artificials " equivalent in plant food content to 30 tons and 10 tons of dung per acre per annum produced no significant effects either on the growth or fruiting of the trees, whereas large increases were obtained on the same soil from similar treatments, especially with dung on bush fruits—particularly on gooseberries—whilst vegetable crops and young nursery stock also responded normally to fertilisers on this soil after the removal of the apple trees used in the experiment. The ploughing in of green crops produced bad effects on apple trees on this soil.

Pickering, in discussing these results, draws attention to the fact that the cropping of the apple trees was affected to a certain extent by the destructive action of spring frosts, but appears to have accepted them as being natural for a heavy and fairly fertile soil.

In the present writer's opinion, however, there is abundant evidence in the Woburn Reports (6) indicating that the soil conditions obtaining at Rigdmont were entirely unsuited for the growing of apple trees and were of such a character as to prevent the trees deriving any benefit from any manurial treatment.

In the experiments on apples at Milbrook, large increases in crops were obtained both from dung and " complete artificials " and in a further series of experiments, in which the treatments " no manure," " complete artificials," " complete artificials " less potash, " complete artificials " less phosphoric acid. and " complete artificials " less nitrogen were given, the following comparative results were obtained which pointed to potash deficiency.

	No Manure.	Complete Artificials.	Omit K_2O	Omit P_2O_5	Omit N.
Relative yields ..	72	100	67	117	103

On this soil large crop increases were also obtained by the use of dung and smaller increases resulted from artificials on gooseberries, whilst similar results over shorter periods were obtained from these treatments on currants and raspberries.

With strawberries no crop increases resulted from any manurial treatment, though dung appeared to prolong the lives of the plants.

Hadlow Experiments.

These experiments were designed to ascertain how crops obtained by manuring with light dressings of dung supplemented by artificial manures, or with artificial manures alone, compared with those obtained by manuring with heavy dressings of dung alone.

The experiments were carried out on apples, plums, gooseberries, currants and strawberries under conditions of clean cultivation on a soil described as a clay loam overlying a deep bed of heavy clay and which was said to be a very poor soil.

The results obtained with all crops excepting strawberries led to the following conclusions :—

1. That a light dressing of dung supplemented with a complete dressing of artificials was as efficient for fruit production as a heavy dressing of dung.
2. That "complete artificials" alone generally gave smaller yields than dung.
3. That the omission of potash from the "complete artificials" resulted in yields much below those from the plots receiving the "complete artificials" and that the plants on these "potash omitted" plots generally failed to make healthy growth.

After ten years of experimenting on apples these investigators wrote: "The outstanding feature of the experiment is the small crops produced on the plots manured with artificials from which potash manures have been omitted." This in 1911, which was a good season, the yields for apples were :—

"Complete artificials" plot	103 cwts. per acre.
,, ,, less potash plot	45 cwts. per acre.

Further, it is stated that the girths at the bases of the trunks of the apple trees on the "potash omitted" plots were on the average 3-in. to 5-in. less than those of the trees receiving potash treatment.

In the experiments on strawberries no consistent results were obtained.

East Malling Experiments.

In experiments on black currants an annual dressing of London dung at the rate of 18 tons per acre over a period of seven years trebled the crop produced over that on the unmanured plot.

Experiments at Ledbury.

These experiments on apple trees are stated to have been carried out over three or four seasons, with the object of discovering whether certain varieties of

biennial fruiting habit could be induced to produce crops annually by a system of manuring which involved both spring and autumn applications of manures. The results are stated to have been positive, but as no check plots were used, further experiments would be necessary before the results can be accepted as being of general application.

Experiments in America.

During the last thirty years a very large number of field experiments, chiefly on apples, peaches and strawberries, have been carried out in America. Although one or two points appear to have been definitely proved by these experiments, the results obtained, on the whole, have been very conflicting. A few examples of the most widely known of these will suffice to show the main character of the results obtained.

New York Experiment Station (9 and 14).

The results obtained in experiments on apples from the application of fertilisers containing nitrogen, phosphoric acid and potash and from dung were so contradictory that no very definite conclusions could be drawn other than that the expenditure on the manures applied did not appear to be justified by the increases in crop resulting from their application.

In some of these experiments heavy applications of nitrogen in a "complete fertiliser" and in dung did not even produce increased tree growth.

Oregon Experiment Station (16).

Very marked effects were produced both on tree growth, type of foliage and fruit production from the use of spring applications of nitrate of soda on apple trees of poor vigour under sod. The yield of fruit was very markedly increased and it was noted that high nitrogenous feeding led to the reduction of colour in the fruit. Previous to treatment the trees showed much yellowing of leaf and were defoliated early in the season.

West Virginia Experiment Station (2 and 3).

Experiments at this Station on peaches and apples showed that for peaches it was possible to obtain large increases in both tree growth and cropping from the application of quickly available nitrogenous fertilisers.

In field experiments on apples similar results were obtained on devitalised trees with nitrate of soda but in many orchards on better soils and where good systems of cultivation were practised the results obtained with commercial fertilisers containing nitrogen, phosphates and potash did not justify their use.

Pennsylvania Experiment Station (20).

In the numerous fertiliser experiments carried out by this Station the results obtained have been decidedly in favour of the use of commercial fertilisers. Of the individual elements nitrogen generally produced the largest increases in crops and dung gave uniformly the most satisfactory results.

Ohio Experiment Station (5).

Very marked results were obtained on poor devitalised apple trees growing on thin soils under sod by the use of nitrate of soda. Acid phosphate was only useful in improving the quality of the herbage of the orchards. Nitrate of soda and sulphate of ammonia produced results more quickly than fertilisers containing organic nitrogen. The returns from potash manuring were negative.

Wisconsin Agricultural Experiment Station (18).

Manurial experiments at this Station have been carried out in relation to the problem of biennial fruiting of apple trees. They have shown that the application of nitrate of soda to trees about three or four weeks before blossoming, strengthens the blossoms and leads to an increased set of fruit.

Experiments on Strawberries (7 and 8).

These results, in general, indicate

1. That ploughing in of clover leys before planting increases yields.
2. That nitrogen from nitrate of soda or dried blood given to plants in the first year after planting, by increasing growth, leads to increased yields in the second year.
3. That nitrogen applied in fruiting years either before or after the crop probably causes the plants to make too much leaf and depresses subsequent crops.
4. That heavy dressings of nitrogen affects the quality of the fruit adversely, decreasing firmness.
5. That phosphates can be safely applied at any season and generally give profitable increases.

No consistent results were obtained from the use of potash salts in these experiments.

CONCLUSIONS FROM FIELD EXPERIMENTS.

It cannot be said that the results of the foregoing experiments have led to any very complete understanding of the problems of the manuring of fruit plantations, but they have served to show how very complicated these problems are.

There are, however, a few very definite points which emerge from them, viz. :—

1. That quick-acting nitrogenous manures, such as nitrate of soda and sulphate of ammonia, will generally produce very marked increases in tree growth and cropping where trees are in poor condition under grass.
2. That in this country large increases are generally obtained on bush fruits from the use of dung and less increases from the use of artificial manures.
3. That the action of phosphatic and potassic manures in orchards and plantations are very variable.
4. That nitrogen is the only element which has been shown definitely to affect the character of the fruit.
5. That there are plantations of apple trees in which ordinary systems of manuring do not produce any measurable effects either on the growth of the trees or on fruit production.

Consideration of these results can only lead to the conclusion that the conducting of further experiments along these lines will not aid us very materially in solving the problem of the manuring of fruit plantations. What is undoubtedly required at the present time to help us towards this goal are fundamental studies in the laboratories of the plant physiologist and chemist on the problems of the nutrition of the various fruit trees and plants. After considerable progress has been made with these studies it will then be time to return to our field experiments with the new outlook which the laboratory investigations will provide.*

Several of the leading horticulturists in America now take this view and in several of the leading Experiment Stations horticulturists, chemists and physiologists are collaborating in studies along these lines.

This attitude of the American worker towards the problem is well illustrated in the papers by Alderman and Anthony read before the American Society for Horticultural Science and referred to previously (1 and 4).

Other Data Available on the Manuring of Fruit Trees.

In addition to the data collected in field experiments, there are data available on various points appertaining to the nutrition of fruit trees from America, Germany, etc. These data generally refer to various pathological

* Following this plan some of the results recorded for the pot experiments described in this paper have been applied by the writer to the diagnosis of the conditions of apple trees undergoing certain differential fertiliser treatments in a small scale field experiment now in progress at the Lancs. County Council Horticultural Station, Hutton, Lancs., and in which some very significant results have been obtained. It was found possible to diagnose the conditions of the trees under experiment by this method.

conditions which have been met with in the field, such as Chlorosis, "Die Back," etc., and these provide additional evidence of the complexity of the problem. For a detailed account of some of this work the reader is referred to "The Fundamentals of Fruit Production" (11), in which there is an excellent Bibliography of such work.

This work, however, has not provided to date anything like sufficient data to enable us to provide the grower with the information he requires to enable him to draw up his scheme of manuring on a scientific basis and hence further investigations are imperative.

EXPERIMENTS AT LONG ASHTON.

In 1920, when the question of carrying out work at this Station on "The Manuring of Fruit Trees" was considered, it was decided that in view of the results obtained in the past the best course would be to study, in the first place, some of the fundamental problems of the nutrition of our fruit plants under the controlled conditions of the laboratory and then to develop field work according to results obtained in the laboratory experiments both on the Station plots and in growers' plantations.

Following this plan series of pot experiments with apple trees and strawberry plants in sand cultures were commenced in the spring of 1921, and since that time these experiments have been extended to gooseberries, black currants and raspberries and certain results have been obtained which we propose to record in this paper.

Before proceeding with the detailed account of these experiments it will be useful at this point to state very briefly the immediate problems which these experiments are designed to study. These are as follows :—

1. How are growth, cropping, etc., of the various fruit trees, bushes and plants affected when they are starved from any one of the essential elements of plant food ?
2. How do plants react to different ratios of the essential elements of plant food ?
3. How do these plants behave in nutrient media of widely differing reactions ?

The reasons for following such lines of investigation are as follows :—

1. In previous experiments in the field, results have frequently been obtained from the use of nitrogen, sometimes by the use of phosphates and occasionally from potash manures. The investigation might reasonably be expected to furnish information regarding the behaviour of plants under conditions of starvation from these elements which could be used as a basis for diagnosis in the field.

2. Much has been written of the importance of certain balances of nutrient elements for agricultural plants, e.g., $\frac{\text{calcium}}{\text{magnesium}}$ ratio, excess of nitrogen as against other elements, etc.

3. Soil reaction is of great importance in agriculture and many data have been accumulated relating to the injurious effects of excessively acid or alkaline reactions of the soil on certain plants. Such data relating to fruit trees are practically non-existent though in horticultural practice it is taken for granted that a supply of lime in the soil is essential for most crops, strawberries excepted.

A few scattered observations on this subject appear in the literature, some writers asserting that lime is essential to promote early ripening of the wood of certain trees (16), that it is necessary for the formation of stone fruits and also that it produces colour in apples, whilst others maintain that for such crops as apples a supply of lime in the soil is not essential (11). Further, it has been the experience of most horticulturists to meet with cases where certain fruit trees fail to make healthy growth on certain limestone soils. The present writer has met with many such cases of apples and plums in the fruit growing districts around Bristol.

EXPERIMENTAL.

Method of Experiment.

The trees, bushes and plants under experiment are grown in quartz sand contained in ordinary unglazed plant pots. Previous to use, all pots are impregnated with paraffin wax by dipping them, after thoroughly drying by heating, in molten wax. A piece of fine mesh copper gauze is placed in the bottom of each pot, which is then filled with sand, the weight of the sand in the pot being determined. 10-in. pots require approximately 10 kilos of sand and 6-in. pots approximately 2.5 kilos. The plants for the particular experiment are then planted. In the cases of apples, gooseberries, black currants and raspberries 10-in. pots are used, whilst for strawberries 6-in. pots are used. Apples, gooseberries and black currants are grown under open-air conditions in a cage and in order to prevent the access of rain to the sand in the pots each pot is fitted across its mouth with a cover of stout tarpaulin. This tarpaulin also prevents rapid evaporation of water from the sand in hot weather. The pots are supported on wooden boards above ground level.

Raspberries and strawberries are kept under a lean-to shed having a glass roof and open sides. The reason for so doing is that the raspberry pots cannot be covered with tarpaulin as for apples, etc., as the plants throw new canes

continuously throughout the season, whilst it is also impracticable to cover the strawberry pots with tarpaulin because of frequent new crown development. These latter pots, however, are fitted with cardboard discs, each disc having a hole cut in the centre to allow of the passage of the foliage of the plant through it. These discs, although immersed in molten paraffin wax previous to use, will not remain firm when subjected to the action of heavy rains.

The sand used is a good quartz sand from Leighton Buzzard, Bedfordshire.

The samples used have shown approximately the following mechanical analysis :—

Fine gravel (particles between 3 mms. and 1 mm.) ..	7.84 per cent.
Coarse sand (particles between 1 mm. and 0.2 mm.) ..	90.06 per cent.
Fine sand (particles between 0.2 mm. and 0.04 mm.)	2.10 per cent.

The amount of matter soluble in concentrated hydrochloric acid is approximately 0.50 per cent.

The plants are fed as desired by means of nutrient solutions, the method adopted being to keep the moisture content at about 20 per cent. of the weight of the dry sand in the pots by adding the necessary amounts of solution to do so. In order to prevent accumulation of salts or of any toxic substances the pots are leached through fortnightly with water. A few pots have not received this leaching treatment in order to determine the effects of non-leaching on certain plants.

The method of making up the nutrient solutions may be illustrated by the procedure adopted for Nutrient Solution A—the complete nutrient solution used in these experiments—other solutions in use being derived from this as described later.

Nutrient Solution A.—The Complete Nutrient Solution.

	Amounts. (grms.)
Sodium Nitrate	5.0
Potassium Nitrate	2.0
Di-potassium Mono-hydrogen Phosphate	1.0
Calcium Sulphate, $0H_2O$	1.0
Magnesium Sulphate, $7H_2O$	1.0
Sodium Chloride	1.0
Ferric Chloride	0.4
Rain Water	To 1 litre.

The solution is further diluted with rain water in the proportion of 1 litre of solution to 9 litres of rain water previous to application.

The concentrations of the various elements of plant food, as parts per million, contained in the solution as applied, together with the concentrations

of some of these elements present in the rain water used in making up the solutions, are given in Table I.

TABLE I.

Element.	Parts per million contained in Solution A.	Parts per million occurring in the rain water used.
Nitrogen	110	Not determined.
Calcium	30	4.5 to 1.4
Magnesium	20	0.9 to 0.36
Potassium	126	0.25
Sodium	175	Not determined
Phosphorus	18	0.03
Sulphur	40	4.0 to 1.2
Chlorine	86	5.0

The pH of solution A. varied from 6.4 to 6.6 according to the reaction of the rain water.

Rain water has been used in the experiments as the use of distilled water would have entailed a very large expenditure. The use of distilled water was tried with a few plants in experiments with apple trees, and as the results obtained were in substantial agreement with those obtained where rain water was used, it was felt that the results obtained with rain water were sufficiently reliable for the purpose in view.

In the early days of the experiments the rain water was collected from the laboratory roof, but during the last season it was obtained wholly from the roofs of greenhouses. The higher figures shown in column No. 3 of Table I. for calcium magnesium and sulphur were obtained on samples of water from the laboratory roof, and the lower figures were obtained with samples from the glass roofs.

The method of deriving the various solutions from solution A. for use in the deficiency experiments described later is as follows :—

Where a base such as potassium, calcium or magnesium is to be omitted, the salt (or salts) containing the base in Solution A. is replaced by an equivalent amount of the corresponding sodium salt, e.g., potassium nitrate is replaced by an equivalent amount of sodium nitrate, etc. Similarly, when it is desired to omit nitrogen or phosphorus, the corresponding sulphates are used and when sulphur is to be omitted chlorides are substituted in place of sulphates.

As under this scheme rather large amounts of sodium sulphate are contained in some of the solutions a special series, using a complete nutrient solution containing a relatively large percentage of sodium sulphate, was included in some of the experiments but this solution did not produce any very pronounced effects and hence the results obtained are not included in this paper.

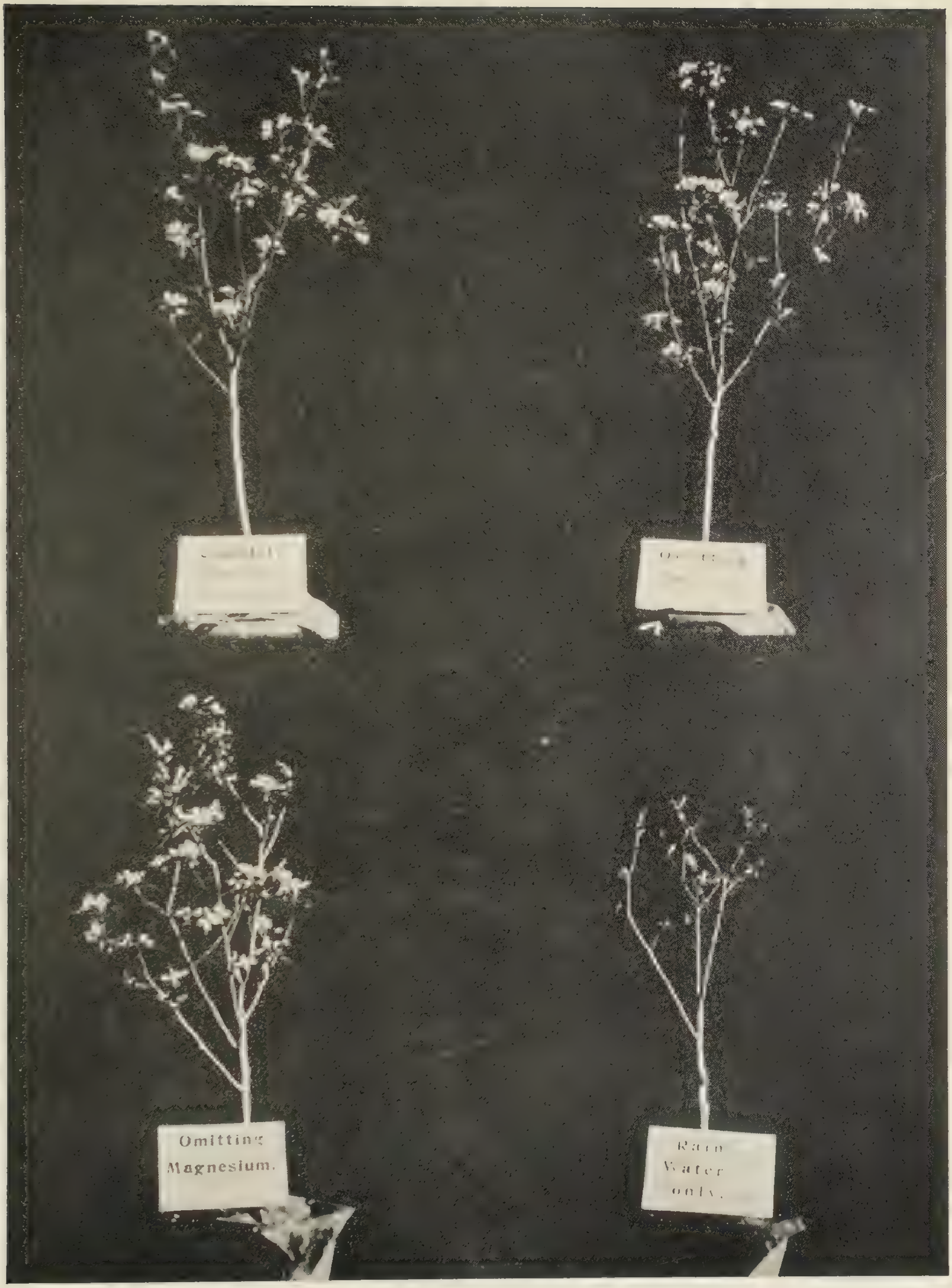

PLATE I.

Blossoming of Apple Trees—May 6th, 1923.

Note the backward and weak condition of the blossom on the tree under the treatment "rain water only."

A.—DEFICIENCY EXPERIMENTS.

These experiments have been carried out on apple trees, gooseberry and black currant bushes and raspberry and strawberry plants, the object being to study the behaviour of the plants when starved of any one of the following elements of plant food—nitrogen, potassium, phosphorus, calcium, magnesium and sulphur. In these experiments series receiving the complete nutrient solution and " rain water only " were included for comparison and in discussing the results, the behaviour of plants receiving Solution A. is regarded as normal from the points of view of shoot growth, foliage characters, blossom characters, fruiting, and root development.

Experiments with Apple Trees.

The experiment was commenced on February 25th, 1921.

Forty two-year-old trees of the variety Cox's Orange Pippin, of which thirty-four were on Broadleaved Paradise stock and the remainder on stronger growing " free " stocks, were used in it. They were divided into eight series, labelled A. to H., after grading by weighing so that the trees in the different series were of similar vigour, each series containing four trees on the Paradise stock (excepting F. and G., in which all trees were on the Paradise stock) and one on a " free " stock.

Previous to planting in the pots, all the trees were root pruned in the Stringfellow method, i.e., all laterals were removed and only the " carrot stumps " left. After planting, all the trees received a normal winter pruning of their shoots. The eight series were fed with nutrient solutions as under :—

Series	A.	Complete nutrient solution			
,,	B.	,,	,,	,,	plus extra Sodium Sulphate.
,,	C.	,,	,,	,,	less Nitrogen.
,,	D.	,,	,,	,,	,, Potassium.
,,	E.*	,,	,,	,,	,, Phosphorus.
,,	F.	,,	,,	,,	,, Calcium.
,,	G.	,,	,,	,,	,, Magnesium.
,,	H.	Rain Water only.			

As previously stated it is not proposed to describe fully the results obtained in Series B. It is sufficient to say that they were generally very similar to those in Series A.

* The pH value of this solution when diluted for application differed from that of the remainder, being approximately 4.7. It has been shown in later experiments that the results obtained by this solution at pH 4.7 are similar to those obtained with the solution after adjusting the pH to 6.4 and the results herein described are therefore attributed by the writer to phosphorus deficiency and not to the difference in pH value from that in solution A.

The experiment is still being continued. The results given below were obtained during the four seasons, 1921-1924.

The data obtained refer to the following points :—

(*a*) Times of opening of leaf and blossom buds.
(*b*) Blossom characters.
(*c*) Foliage characters throughout the season.
(*d*) Shoot growth.
(*e*) Defoliation.
(*f*) Condition of barks.
(*g*) Character of fruits.
(*h*) Root systems.

(*a*) *Times of opening of leaf and blossom buds.*

The times of opening of leaf and blossom buds were delayed by three of the treatments given, viz., C, E, H. All the trees in all series commenced growth simultaneously in 1921, but by 1922 those in the above-named three had fallen behind and it was obvious that the buds in these series were much weaker than in the others.

Observations made on April 3rd, 1923, on this point will illustrate the condition for that season.

Observations made on April 3rd, 1923 :—

Series A, D, G, F.—Condition of bud break similar. Buds well advanced.
Series E, C, H.—A few buds just commencing to break.

All branches were cut away from the trees in January, 1924. The following illustrates the order in which the trees started into growth in spring, 1924, after this operation.

Observations made May 11*th,* 1924 :—

Series A, G.—In all plants the buds had started into growth.
Series D, F.—Slightly behind A.
Series C, E, H.—Buds were practically dormant.

(*b*) *Blossom characters.*

Observations were made on the blossom characters of the trees in 1922, 1923. In both seasons it was noted that the actual times of blossoming were delayed in the series C, E, H, which was apparently due to the weakness of the blossom buds. Thus on May 4th, 1923, in Series A, D, F, G, all the trees had flowers open, whilst in Series E, C, H, there were no trees with open flowers. The condition of the blossom on May 6th, 1923, is shown on Plates I. and II.

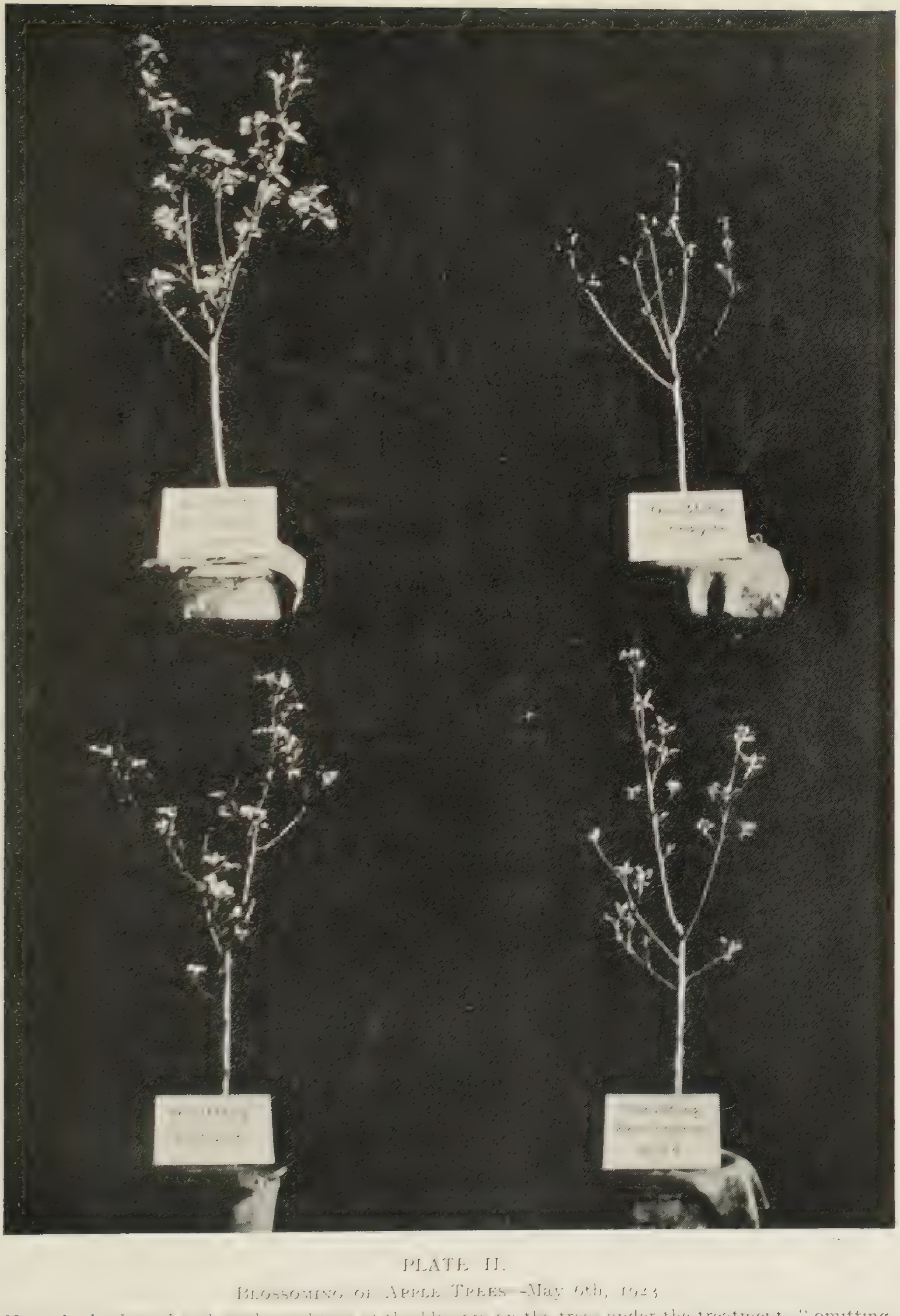

PLATE II.

Blossoming of Apple Trees—May 6th, 1923

Note the backward and weak condition of the blossom on the trees under the treatments "omitting nitrogen," "omitting phosphoric acid."

It was obvious, too, that in 1923 after the heavy blossoming of the trees in 1922, those in Series C, E, H ,were not able to blossom profusely again. This point is brought out in the data for blossom counts for 1922, 1923, given in Table II.

TABLE II.—BLOSSOM COUNTS ON APPLE TREES.

Season, 1922. *May* 20*th. Data for Trees on Paradise stocks.*

Series.	Number of trees blossomed.	Total Trusses.	Total Flowers.	Average Flowers per Truss.
A.	4	80	481	6.0
C.	4	94	486	5.2
D.	4	105	577	5.5
E.	4	99	549	5.5
F.	5	129	713	5.5
G.	5	131	646	4.9
H.	4	63	273	4.3

Season 1923. *May* 8*th. Blossom Trusses.*

Series.	Tree * No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	Totals.
A.	33	46	34	30	22	165
C.	19	4	Nil	1	Nil	24
D.	16	32	19	23	21	111
E.	5	20	13	3	2	43
F.	42	41	20	30	32	165
G.	50	40	36	13	8	147
H.	29	3	Nil	2	1	35

(*c*) *Foliage characters* (see Plate III.).

Characteristic types of foliage were developed by the trees in the different series and it appears to be possible to associate certain very definite leaf symptoms with certain deficiencies. It will be shown later that some of these symptoms are also produced by other plants under the respective treatments.

Before describing these leaf types it may be as well to state at this point that some of the symptoms appear to be accentuated by certain ratios of the elements in the nutrient solution. Certain of these cases will be dealt with in a future issue of this journal. It will be sufficient for the present to instance the case of leaf scorch which has been associated with potassium deficiency in these experiments, the incidence of which appears to be greatly influenced by the ratio $\frac{\text{nitrogen}}{\text{potassium}}$ in the nutrient solution. Thus leaf scorch has appeared in every series excepting Series C, E, H, each year, and we have shown the occurrence in Series A to be due to the above ratio being too wide in the solutions used.

* Freestock in each Series excepting Series F, G.

Series A.—The foliage in this series was a healthy green and the leaves were well developed and of normal character. They became affected with leaf scorch each season though to a much less extent than in Series D.

Series C.—From an early date in 1921 the foliage of these trees was very sparse. The leaves were always small and pale yellowish green in colour with a tendency to form reddish tints. During the seasons 1923, 1924, the leaves were practically confined to the tips of the shoots. They were practically free from leaf scorch in all seasons.

Series D.—During the first few weeks of each season the foliage of these trees looked exactly like that in Series A, but very soon the leaves fell behind in size, whilst a dull green colour was developed and finally the leaves became severely affected with marginal leaf scorch, which condition was followed by defoliation.

Thus in 1921 scorch was in evidence by the end of June, in 1922 by May 20th, in 1923 by May 13th, and in 1924 (after severe pruning and in a wet season) by June 27th.

Prior to scorching, the leaves generally showed symptoms of chlorosis around their margins, the pale areas eventually extending towards the midrib along the areas between the veins. The leaves of this series also differed from those of the others in that they showed a tendency to curl at the edges towards their under surfaces. This condition was also noted in black currants, gooseberries, raspberries and strawberries and appeared to be a characteristic of the treatment.

Series E.—The foliage characters exhibited by the plants in this series were very characteristic, which is not in agreement with certain observations previously recorded (11).

No very definite symptoms were noted until towards the end of the first season when the foliage began to show a bronzed appearance. This bronzing of the leaves was very marked during all subsequent seasons from a very early date—in 1923 from as early as May 20th.

The bronzing often commenced as a dull purpling and was accompanied by purple spots dotted over the leaf areas. The amount of foliage carried during the last two seasons was similar to that in Series C. and was confined to the tips of shoots. In fact, the treatment was practically as drastic as that of omitting nitrogen during the latter half of the period of the experiment. As in Series C, under this treatment, practically all lateral buds appeared to become dormant owing to weakness.

Series F.—The results obtained in this series were rather unexpected. Instead of obtaining a weak, poorly developed type of foliage exhibiting much chlorosis, such as is generally obtained as the result of calcium deficiency (17), the amount of foliage on the trees was usually larger than that in Series A, whilst

Shoot Growth and Foliage Characters of Apple Trees Undergoing Various Treatments—July 31st, 1924.

Note the failure of the trees to make shoot growth in the series "omitting nitrogen," "omitting phosphoric acid," "rain water only." The tree receiving "omitting potash" treatment is practically defoliated from leaf scorch. The shoots of all trees had been cut back to the main stem during the preceding winter.

PLATE III

the leaves were very large and in certain seasons showed a tendency to remain on the trees after those in Series A. Whilst it is obvious that the plants must have had considerable stores of calcium previous to the experiment and that they must have obtained a certain amount from the rain water given and that complete starvation from calcium would most probably result in restricted growth, chlorosis of foliage and death, yet it is of great interest to note the behaviour of these trees in this experiment. We have also run a similar series using distilled water and have obtained similar results whilst similar results were obtained with strawberries even in the third season of the experiment.

The phenomenon is being investigated by the plant physiologist and already significant results—as yet unpublished—have been obtained.

Finally the observation may throw some light on certain observations previously recorded on the effects of lime on fruit trees in the field (16). Apart from their size, the leaves did not appear to differ from those in Series A, excepting that at certain intervals under conditions of bright sunshine they occasionally appeared to be slightly chlorotic.

Series G.—Some very interesting observations were made on the foliage in this series. The foliage was generally very luxuriant during the very early parts of the seasons and the leaves attained a large size, being somewhat similar to the leaf size in Series F. Very soon after reaching full growth they showed symptoms of breakdown. These symptoms took the form of what we have termed " blotch "—i.e., the death of large patches of tissue in the centres of the leaves occurred, which patches became brown in colour. After this stage of breakdown was reached, the affected leaves fell and in this manner the trees lost all their foliage excepting a little at the tips at an early date in each season. Thus blotching was severe in 1922 by June 8th, in 1923 by May 13th, and by June 27th in 1924.

This effect of magnesium starvation may be of importance in cases where growers rely entirely on " artificials " for manuring since it appears to be closely related to the supply of potassium available to the plant.

Series H.—The foliage of the trees in this series was usually very similar both in amount and character to that in Series C, with the exception that the colour did not generally show so much yellowing whilst tints of a more intense red colour were developed.

In making various observations on the foliage of the trees, one interesting fact was noted with reference to the greater resistance offered to the conditions of malnutrition by the foliage of the trees on the strong growing " free " stocks as against that of the trees on the weaker Paradise stock. This point is illustrated in Plate IV. which shows the relative susceptibility to leaf scorch of trees in Series D, on a " free " stock and on Paradise stock.

(*d*) *Shoot growth.*

TABLE III.

SHOOT GROWTH OF APPLE TREES.

Series.	Season 1921.			Seasons 1921-1923*.			Season 1924†		
	No. of trees.	Average per tree total shoot growth. mms.	Length of longest shoot mms.	No. of trees.	Total length shoot growth mms.	Total weights shoots as prunings. gms.	No. of trees.	Total length shoot growth mms.	Total weights shoots as prunings. gms.
A.	5	939	256	5	4240	656	4	3945	58.7
C.	5	560	133	5	330	284	4	100	Nil
D.	5	608	139	4	2010	331	3	2110	21.0
E.	5	764	161	5	1330	344	3	230	Nil
F.	5	1120	226	5	4330	776	4	5275	74.1
G.	5	924	177	5	3010	630	4	3225	55.1
H.	5	629	134	5	520	294	4	120	Nil

* Data for length of shoots relate to growth made during season 1923. Those for weights relate to weights of shoots made over seasons 1921-1923.

† Data for trees on Paradise stock only.

It was not possible to take prunings from trees in Series C., E., H.

PLATE IV

Apple Trees on Broad-leaved Paradise Stock and a Strong "Free" Stock respectively—July 31st, 1924.

Showing the greater resistance of the strong "free" stock to conditions conducive to leaf scorch. The tree on the Paradise Stock had shed most of its foliage after "scorching."

Data are presented in Table III. which indicate the character of the shoot growth made by the trees at various periods during the experiment. Those given for season 1921, and seasons 1921-1923 were influenced to some extent by the fact that most of the trees blossomed during those seasons and thus the results do not properly represent the total growth effort of the tree. For this reason data for " free " stocks and Paradise stocks have not been separated.

The data for 1924, however, were obtained after removing all growth made by the trees during the period 1921-1924, and represent the total effort towards shoot growth which the trees were able to make following such treatment.

Consideration of these results shows the following facts :—

1. The trees in Series F made the greatest shoot growth.
2. Shoot growth in Series G was not greatly restricted.
3. Shoot growth in Series D was restricted.
4. The trees in Series C, E, H, were not able to make any appreciable amount of shoot growth during 1924.

It will be noted later in the paper that results similar to these have been obtained with other plants.

(*e*) *Defoliation.*

In making observations on defoliation in the different series it was evident that defoliation in some series did not always result from a gradual closing down of growing processes but was due to the leaves being unable to resist certain outside stimuli. In such cases, where defoliation occurred in early or mid-season, the plants often developed a new set of foliage. Defoliation of this character generally followed severe leaf scorch, especially in Series D, or leaf blotching in Series G.

The observations recorded indicate that growth ceased early in Series C, E, H. Defoliation was also always premature in Series G, and was always preceded by blotching.

In series D, where leaves were not severely affected with leaf scorch they were retained as long as in Series A.

The general order of defoliation is shown by the following typical observations made on the order of retention of foliage in seasons 1921-23.

Observations on Order of Retention of Foliage.

Season ;

1921—Nov. 5th.—F, A, E, D, G, H, C.

1922—Oct. 24th.—F, A, D, G, E, C, H (H defoliated).

Oct. 31st.—F, A, D, G, E, C, H (C, H defoliated).

Nov. 7th.—F, A, D, G, E, C, H (E, C, H defoliated).

Season:

1923—Oct. 14th.—A, F, D, G (foliage very sparse), C, E, H (practically defoliated).
Nov. 1st.—A, F, D, G, H, C, E (C, E defoliated).

The tints developed during the period of defoliation appeared to be determined largely by the treatments and hence may be found to be very helpful in the diagnosis of deficiencies in the field, though much experience in field work will be necessary before such indications can be usefully applied as certain of these can be produced by other factors which presumably affect the metabolic processes of the plants in similar fashion. Thus, in Series A the predominant tints were orange and reddish-orange; in C they were as in A, but more pronounced; in D tints were suppressed, only a little yellowing appearing in addition to leaf scorch symptoms; in E the foliage exhibited marked bronzing; in F high tints as in A were developed; in G blotching and high tints as in A appeared; in H the tints were as in C, but there was less yellowing and the red tints deeper.

In general, it may be remarked that the characteristics described in the section on foliage characters became more pronounced towards the period of defoliation, whilst where no characteristic symptoms were developed, orange and red tints were developed during defoliation. This appears to hold for all plants which have been used so far in these investigations.

(*f*) *Colour of Barks.*

The barks of the trees in Series C and H showed up as very light brown against those of the other series, especially so after rain.

(*g*) *Characters of Fruits.*

The crops obtained were not large enough to allow of very extensive observations being made on the characters of the fruits.

A few observations made on the 1922 crop are, however, worth recording. These were as follows:—

Series A.—The fruits were coloured to a medium extent, the skins being clear with a high polish. The flesh was yellowish in colour and the fruits had the true Cox flavour.

Series C.—The fruits were small and very highly coloured. The skins were without polish. The flesh was white and hard. The fruits were rather acid in taste and lacked the high ethereal flavour characteristic of the variety. The fruits, in fact, resembled the highly coloured fruits generally produced under grass orchard conditions.

Series D.—The number of fruits was insufficient to obtain very definite information. On the whole it appeared that acidity, sweetness and flavour were all less than in Series A. The colours of skin and flesh were as in Series A.

Series E.—The fruits were as in Series A in colour and polish, but were very soft in texture. The flesh was yellow as in A. The flavour was very unpleasant and resembled that of fruits when they commence to decay in store. The acidity appeared to be high and the fruits lacked sweetness. This lack of quality and high acidity in fruits in Series E were also noted with gooseberries, black currants and strawberries. It is of interest that quality in wines is stated to be associated with the content of phosphoric acid (19).

Series F, G.—No fruits were available.

Series H.—The colour and general appearance of the fruits were as those in Series C. The flesh was almost white and very hard. The fruits were very woody to taste and the flavour resembled that of the variety, though in a very diluted form.

(*h*) *Root Systems.*

The trees were removed from the pots at the end of seasons 1921 and 1922 and their root systems examined.

The following is a summary of the observations made on those occasions on the trees on the Paradise stock :—

December, 1921 :

Series D.—The amounts of roots formed in this series were smaller than in any other series. The root fibre was of a similar degree of coarseness to that in Series A. There was a lack of fine fibre.

Series C, H.—The root systems in these two series were similar in amount and type of fibre. The amounts in each series were almost equal to those in Series A, but their textures were much finer.

Series F.—The roots were less than those in Series A. The type of root fibre was thin as in Series C, H. There was much recent growth.

Series G, E, A.—The amounts of root and type of fibre made by the trees in these series were similar. They were well supplied with both coarse and fine fibre.

The roots in Series G had many blackened root tips, probably indicating root killing. This observation was made for this treatment in other experiments.

December, 1922 :

Order of size of root systems.

Series A, G, F.—Practically identical.

Series E.—Smaller than in Series A., etc.

Series D, C.—Similar in size and smaller than in Series E.

Series H.—Very small.

The roots in Series A, F, G were normal in character, showing good growth of coarse and fine fibre.

Those in Series E showed a characteristic yellow colour of the fibre and there was a lack of recent growth.

The roots in Series D lacked fine fibre, whilst those in Series C, H consisted almost wholly of fine fibrous rootlets.

On this latter date the root systems of two trees per series were pruned in the Stringfellow method before replacing in the pots and these were again examined on 1st January, 1924.

The weights of roots removed are given in Table IV.

TABLE IV.

WEIGHTS OF ROOTS REMOVED, DECEMBER, 1922.

Tree Number.	Weights roots removed. grammes.	Roots Totals. grammes.
A.2 A.5	90 95	185
C.2 C.5	79 64	143
D.2 D.5	66 60	126
E.2 E.5	114 78	192
F.2 F.5	162 148	310
G.2 G.5	108 53	161
H.2 H.5	64 44	108

There were large differences between the two root systems in any series on this occasion as the treatment almost killed some of the trees and it required almost the whole of the season for them to overcome the check.

Observations on the better roots showed the following characters.

Series A.—Roots fairly normal in character.

Series C.—Root systems very small. Fibre thin and of starved appearance.

Series D.—Root system small. Both coarse and fine fibre thinner than in Series A, and there was a deficiency of fine fibre.

Series E.—Roots very small. Fibre thin and brown.

Series F.—Similar to Series A, but coarse fibre, thinner than in Series A.

Series G.—Roots similar to F. There was much blackening of the root tips.

Series H.—There had been practically no root formation.

SUMMARY OF RESULTS ON APPLE TREES.

1. The times of the opening of leaf and blossom buds were delayed by the treatments given in Series C, E, H.
2. The blossoms in Series C, E, H, were much weaker than those in the other series and the amounts of blossom were greatly reduced in these series.
3. Very definite foliage characters were produced by each of the treatments.
   - In Series A the foliage was normal in character.
   - In Series C the amount of foliage was small and the leaves were small and yellowish green in colour, with reddish tinting.
   - In Series D the foliage was less in amount than in Series A, the leaves were smaller, were dark green in colour, tended to curl towards the under surfaces and developed marked leaf scorch.
   - In Series E the foliage became restricted to the tips of shoots. The leaves developed a characteristic dull purplish bronze appearance.
   - In Series F there was a large amount of foliage developed. The leaves were generally larger than in Series A.
   - In Series G the leaf size was similar to that in Series F. The leaves developed a characteristic type of blotching in their centres.
   - In Series H the condition of the foliage was usually similar to that in Series C, but the tints developed were of a more intense red.
4. Shoot growth was longest in Series F. After the first season it became greatly restricted in Series C, E, H. It was also only moderate in Series D.
5. Premature defoliation resulted from two conditions:
   - (*a*) Cessation of growth activities as in Series C, E, H.
   - (*b*) Following on certain pathological conditions such as leaf scorch and blotch.

   The trees in Series C, E, G, H were usually finally defoliated in advance of the other series. Defoliation was accompanied by definite kinds of tinting in the various series.

6. The barks in Series C, H were lighter brown in colour than those in the other series.
7. The fruits in Series C, H were very highly coloured and were hard in texture. Those in Series E were soft and of poor quality.
8. During the first year the growth of the root-systems was restricted most in Series D, C, H.

   The roots in Series D lacked fine fibre.

   In Series C, H the fibre was thin.

   There was evidence of root killing in Series G.

   After three years under experiment the root pruned trees in Series C, E, H, D made very poor roots during the season following a root pruning operation.

THE TREATMENT OF SEEDLING APPLE TREES TO INDUCE EARLY FRUITING.

By G. T. SPINKS.

One of the difficulties which confronts the breeder of new varieties of apples and other top fruits is the great length of time which usually elapses before a seedling plant begins to bear fruit. A seedling apple tree rarely, if ever, bears any fruit until it is about six years old, and frequently this length of time is prolonged to about ten years.

It is obviously desirable to shorten this period of unfruitfulness as much as possible and this note is a record of some attempts to do this. Young apple seedlings always exhibit a definite " juvenile " habit of growth differing from the habit of an " adult " tree which has started bearing. Different seedlings naturally show differences in habit, but in general it may be said that they all show the following characters. The branches bear, often on the current year's wood, many lateral shoots, which are either long, thin and whippy, or are short and thin and almost spiney in character. Short lateral growths on the current year's wood are often terminated by thorns instead of buds. The leaves are small and the rosettes surrounding the terminal buds of short lateral growths, " lambourdes " and " dards," consist of few and small leaves which are evidently unable to supply enough nourishment to the bud to convert it into a fruit-bud.

These " juvenile " characters, of course, appear only on *seedling* trees and not on other young trees which consist of a stock on which has been worked a graft or bud taken from an " adult " tree. Apparently a seedling must grow out of its " juvenile " state before it commences to fruit, and the object of the experiments to be described was to find some method of shortening this " juvenile " period. Obviously an experiment of this sort cannot be conducted with any great accuracy, as all the seedlings used are distinct individuals and behave in different ways. An endeavour was made, however, to obtain some indication of the effect of different methods of treatment on the length of the juvenile period. The methods adopted were some of those which were known to accelerate fruiting when used on ordinary varieties of apples which have passed out of their juvenile state.

PLAN OF EXPERIMENT.

The experiment was started on March 1st, 1921, by planting out sixty-five one-year old apple seedlings in the plantation. These trees were grown from seed of unknown parentage and were, in fact, simply a collection of seedlings such as

are used as " free " stocks; but those used were all well grown and as uniform as it was possible to obtain them. They were planted fifteen feet apart in three long rows, the distance between the rows also being fifteen feet. The trees were divided into groups of five and a different treatment was arranged for each group, as follows :—

(1) No pruning ; no treatment of any sort.
(2) Shaping.
(3) Shaping, ringing.
(4) Shaping, root-pruning.
(5) Shaping, manuring.
(6) Shaping, manuring, ringing.
(7) Shaping, manuring, root-pruning.
(8) Light pruning.
(9) Light pruning, ringing.
(10) Light pruning, root-pruning.
(11) Light pruning, manuring.
(12) Light pruning, manuring, ringing.
(13) Light pruning, manuring, root-pruning.

Some of the above terms need an explanation.

Control.—The trees in group (1) were simply allowed to grow naturally, without pruning or any manurial or other treatment, from the time they were planted as maidens.

Pruning.—" Shaping " indicates that the trees were pruned in winter for two or three years after planting merely to train them into bush form ; no other pruning was given to these trees.

" Light pruning " consists of the above treatment and, in addition, cutting out inter-crossing branches and strong lateral shoots and a light tipping of leaders. No spur-pruning was attempted and no summer pruning was done. No attempt was made to adhere to a rigid plan of pruning, as this would be useless when dealing with seedling trees which have all different characters. It was quite expected that any pruning would delay fruiting, but information was wanted regarding the amount of delay which would result from regulating the shape and size of the trees and the possibility of counteracting this delay by the other treatments given.

Manuring.—A mixture of artificial manures was applied to the trees in groups (5), (6), (7), (11), (12) and (13) in March or April of each year, except immediately after planting. The mixture consisted of sulphate of ammonia, sulphate of potash, and superphosphate in the proportions 2 : 2 : 5, and it was applied at the rate of 9 cwt. of the mixture per acre, i.e., about $3\frac{1}{3}$ oz. per square

yard. In 1922, one square yard round each tree was treated at this rate, in 1923, four square yards, and in 1924, nine square yards.

Ringing.—The ringed trees were treated as follows :

On May 16th, 1922, the main stem of each tree was given a ring consisting of a single knife cut extending down to the cambium all the way round the stem.

On July 4th, 1923, the main stem of each tree was again ringed, but in this case two knife cuts were made one-eighth inch apart and the ring of bark between them was completely removed.

Root-pruning.—The trees to which this treatment had been allotted were root-pruned on November 25th, 1921 and December 18th, 1923, all roots being shortened to 9 to 12 inches on the second occasion.

Other treatments. In addition to the sixty-five trees given in the above list ten trees were used as scions for grafting, three scions being obtained from each tree. Ten scions, one from each tree, were head-worked on established bush trees, about eight years old, which had been headed back. The remaining twenty scions were worked on Malling Type 9 stocks. The only stocks available were some which had only recently been planted, so that the scions had only a poor chance of making good growth.

A further five seedlings were planted in eight-inch pots in March, 1922, that is a year later than all the others, but as they were two years old when planted they are comparable with the other seedlings, which were only one year old when planted. These plants in pots were given liberal dressings each year of the same mixture of manures which was applied in the field, and they were lightly pruned.

DISCUSSION OF RESULTS.

It is not proposed to set out in detail the observations made on the various trees, but merely to give a summary of the results obtained. In October, 1924, when the trees were five years old, it was seen that the result of the experiment was largely negative, in so far as up to that time no trees had produced flowers, and there would apparently be no buds producing flowers in 1925. Trees in the different groups, however, showed distinct differences which indicate which treatments had favoured the earliest fruiting.

The trees which had been *root-pruned* were on the whole smaller and growing less vigorously than any of the others. But this dwarfing effect had not been accompanied by any formation of flower buds or by any other signs of having reached the "adult" stage. On the contrary, all the trees were distinctly "juvenile" in habit, with the exception of four which showed slight traces of growing out of this condition. It was evident that the root-pruned trees would be the last of all to produce fruit.

The *ringed* trees showed the same characteristics as the root-pruned trees but in a less marked degree. They were slightly less vigorous than the unringed trees. About six trees were definitely "juvenile" in character, eight were beginning to grow beyond that state, five were almost adult in appearance, and one was judged to be definitely "adult."

The trees receiving *no ringing or root-pruning* were the most vigorous, and of these three seemed to have reached the "adult" state, eight had nearly reached that state, while seven were still in the "juvenile" stage.

The *manuring* seemed to have produced slightly more vigorous trees, but the increase in vigour was not at all marked. The manured trees, on the average were also more "adult," but here again the difference was small. On the whole the more vigorous trees were also the more "adult" in character.

Pruning cannot be said to have had any consistent effect on the character of the trees, and certainly no significant difference between the shaped and pruned trees could be seen. During the short length of time for which the experiment was carried on it was really only in the last year that there was any difference in the treatment of these two sets of trees. The entirely unpruned trees varied considerably in the degree to which they had reached the adult state, and as there were so few of them it cannot be said with certainty that, on the average, they showed more or less of the adult character than the pruned trees. On the whole, the trees which were manured and lightly pruned, but not otherwise treated, seemed to have made the best progress of any in the experiment, but this may be mere coincidence.

Trees *grafted* on Type 9 stock made very poor growth and were mostly juvenile in appearance, but they were grafted under such poor conditions that they cannot be said to have had a fair chance. In this connection another set of seedlings worked on dwarfing stocks may be mentioned, though they do not form a part of this experiment. In 1920 several hundred buds from young hybrid apple seedlings were worked on Malling stocks, Types 4, 8 and 9, and in February, 1922, these were planted out here. None of these trees have yet blossomed and very few show any fruit buds for 1925. Trees budded on similar stocks at the same time, the buds from which had been taken from seedlings already in the "adult" state, bore blossom when two years old.

The seedlings *headworked* on older trees have grown vigorously and most of them seem to have reached the "adult" state, but they have not flowered yet and show very few, if any, fruit buds for 1925.

The trees *in pots* are still entirely or partially "juvenile" in character and show no signs of flowering yet.

This experiment has now been concluded, as, although none of the trees have yet come into bearing, it was obvious that the special methods which were being tried were not having the desired effect.

SUMMARY.

From the above results it appears that any treatment which restricts growth, such as ringing, root-pruning, working on dwarfing stocks and growing in pots, does not induce earlier fruiting in very young seedlings. On the contrary, it tends to keep the trees longer in a " juvenile " state and so delays fruiting. Probably the best way to obtain early fruiting is to encourage vigorous growth which will bring the tree to its " adult " state at the earliest possible date. When this state has been reached a tree which still refuses to bear can be brought into fruit by some such method as ringing : this method has actually been used with considerable success on " adult " but barren seedlings.

THE EFFECTS OF LEACHING WITH COLD WATER ON THE FOLIAGE OF THE APPLE.

By C. E. T. MANN and T. WALLACE.

During the past summer observations made in the plantations at Long Ashton and in other districts in the West showed the foliage of several varieties of apples to be badly damaged by a very characteristic form of spotting. Among the varieties on which this damage was observed were Cox's Orange Pippin,* Stirling Castle, King's Acre Pippin and Allington Pippin. The severity of the trouble ran in the order given for the above varieties, but Cox was much more severely damaged than any other. Observations made on this variety on June 24th showed that the mature, first formed leaves were severely spotted and that defoliation was extensive in the worst cases. The damage was much less pronounced in the other varieties quoted, while such varieties as Bramley's Seedling, Worcester Pearmain and Newton Wonder were quite unaffected.

Detailed observations on the leaves of Cox's Orange Pippin showed that in the early stages of the trouble minute purple spots and in more severe cases purplish blotches, appeared on the leaf blades. Later stages showed small areas of dead tissue in the centres of the spots or blotches, which appeared to increase in size progressively. The purplish discolouration persisted as a margin to the dead region and probably indicated an intermediate stage in the breakdown of the leaf tissue. The progressive nature of the trouble was often clearly shown in large single spots which exhibited a series of concentric markings indicating intermittance. The breakdown of tissues was not continuous, but periods of check occurred.

The past season was abnormal in respect of rainfall, as the figures presented in Table I. show. It appeared significant that this spotting trouble was so markedly severe in such a season.

In this connection some observations made in an independent investigation are of interest (3). Four series of one year old trees of Cox's Orange Pippin growing in sand cultures were prepared for different nutrient treatments. Two trees from each series were placed in an orchard house, while the remainder were set up in the open. On June 23rd, it was noted that the foliage of the trees in the open was suffering from spotting trouble, apparently irrespective of the nutrient treatments, whilst the foliage of the trees similarly treated but protected from rain was unaffected. These observations suggested that excessively wet

* It is not intended at present to definitely connect the damage here described with the form of spotting, occurring on the leaves of Cox's Orange Pippin, frequently termed "Cox's Spot."

conditions might be largely responsible for such foliage damage. The alternation of wet and dry periods would account for the intermittent character of the trouble.

TABLE I.

Monthly Rainfall Record at Long Ashton for Corresponding Periods of Seasons 1923 and 1924.

Month.	Rainfall in inches.	
	1923.	1924.
March ..	1.34	1.80
April ..	2.70	2.98
May ..	1.88	4.32
June ..	0.51	4.45
July ..	2.35	5.01
August ..	3.74	5.79
September ..	2.69	3.64
October ..	4.47	6.38
Totals March-Oct. ..	19.68	34.37

PART I.

To test whether the spotting effects described above could be produced on apple leaves by alternate immersion in water and exposure to air a series of experiments was devised. The methods employed, with the results obtained, are described in the following section.

EXPERIMENTAL.

A.—Experiments with Detached Leaves.

Exp. I. On June 25th healthy leaves were collected from bush trees of Cox's Orange Pippin and Bramley's Seedling. Single samples of each variety, each consisting of ten leaves with petioles removed, were immersed in 250 c.c. of cold distilled water. Corresponding samples were removed at intervals and spread on blotting paper for exposure to the air. Observations made on the leaves, after stated periods of immersion and exposure, are recorded in Table II.

Exp. II. From observations in the field and in the foregoing experiment, where it was noted that the water became coloured after the leaves had been immersed for a few hours, it was thought that excessive washing with water might result in the removal of soluble substances from the leaves. Should this be the case, chemical analysis of the water in which leaves

have been immersed for some time should give results of interest. Previous work has shown that the potassium compounds occurring in plant tissues are all readily soluble in cold water (1 and 3). Therefore, should removal of solutes occur on immersion of a leaf in water, determinations of the amounts of potash contained in the external solution after successive periods of immersion should afford figures indicative of the rate and extent of this removal.

Procedure. Healthy leaves were collected on June 27th from the two bush trees of Cox and Bramley. The petioles were removed and for both varieties three samples of leaf-blades, each sample approximately 20 grams, were quickly weighed out.

Samples 1. These were dried to constant weight at 98° C. The dry matter, total ash and the total potash (K_2O) in the ash were determined for both samples. [Table III. (1).]

Samples 2. Each sample was immersed for twenty-four hours at room temperature (approximately 18° C.) in a litre of distilled water contained in a litre cylinder. The liquid was poured off and filtered. The leaves were replaced in a second litre of distilled water and the whole process repeated three times. Finally, the leaves were immersed as above for seven days and on removal they were dried, ashed and the potash content of the ash determined as for Samples I. The four extracts obtained for each variety were evaporated to dryness separately and the residues ashed. The amounts of potash contained in the ashed residues were determined. [Table III. (2a and b).]

Samples 3. Both samples were cut into small pieces and pounded in a mortar. The crushed samples were transferred to litre cylinders and the volumes made up to 1 litre with distilled water in each case. Extraction was allowed to proceed for twenty-four hours. At the end of this period the extracts were decanted off and filtered. The residues were washed several times and the successive washings, after filtering, were added to the extracts. The whole of the washed residues were dried to constant weight. The potash content of both extracts and residues were determined as in Samples 2. [Table III. 3a and b).]

The results obtained for the three samples of each variety are summarised in Table III. and graphically represented in Figure I.

B.—Experiments with Shoots bearing Healthy Leaves.

The treatments described above are obviously much more drastic than any treatment the leaves might receive under natural conditions. The cut petiole

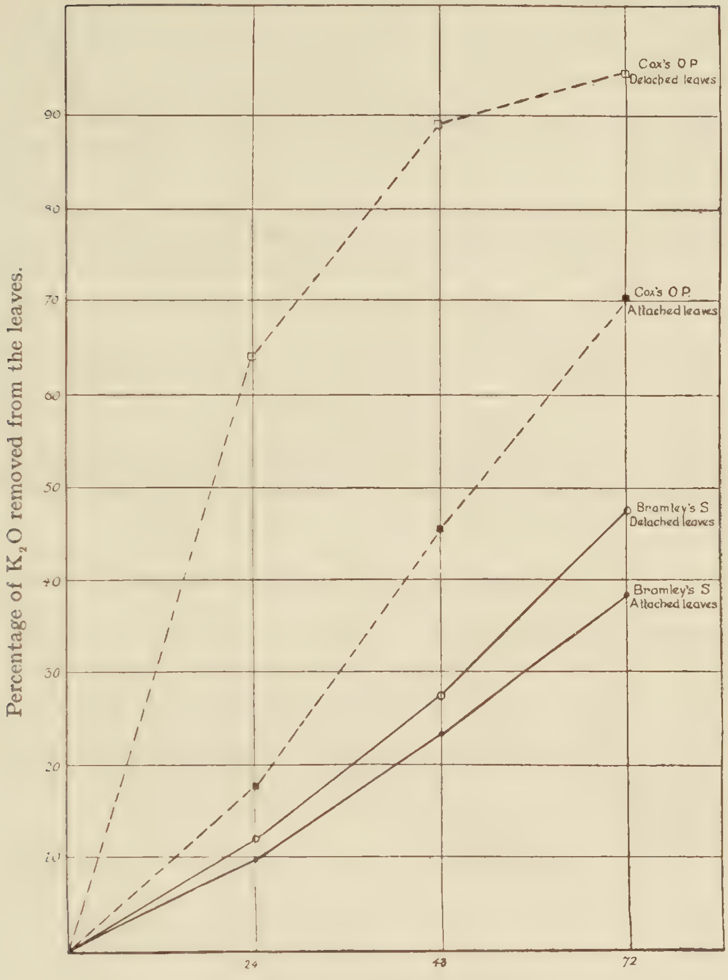

FIG. 1.—Showing the course and extent of removal of potassium compounds from the leaves of apple by immersion in cold water.

quite possibly afforded a channel for the escape of dissolved substances from the leaves. Therefore, it was considered advisable to repeat the experiments described above under less severe conditions.

Exp. III. On August 11th, healthy shoots of the current year's growth were selected from trees of Cox and Bramley. The original trees from which material was obtained for the previous experiment with Cox were, at this date, so badly affected that material was obtained from two-years old trees in the nursery bed. The original source of Bramley material was still quite free from the trouble.

Shoots about 20 cm. long, after sealing the cut ends with soft paraffin wax, were immersed singly in a litre of distilled water in a litre cylinder. After definite periods of immersion and subsequent exposure to the air, observations were made on the foliage as described for the experiment with detached leaves. These observations are recorded in Table IV.

Exp. IV. Two further samples for each variety, composed of shoots about 20 cm. long and bearing approximately 20 gms. of foliage, were selected.

Samples 1. From these shoots, the leaf blades were removed and weighed for analysis; the dry weight, total ash and potash in the ash were determined (Table VI.).

Samples 2. After sealing the cut ends of these shoots with soft paraffin wax, they were subjected to the same treatment of immersion as the detached leaves in Exp. 2. The results of determinations of potash in the residues of the leaves and extracts obtained are summarised in Table V. (2 and 3), and graphically represented in Figure I.

Experimental Results.

A.—Experiments with Detached Leaves.

Table II.

The Effects of Immersion in Water and Subsequent Exposure to Air on the Leaves of Cox's Orange Pippin (C) *and Bramley's Seedling* (B).

Sample.	Time of Immersion. Hours.	Time of Exposure. Hours.	Observations.	
			Cox.	Bramley.
C.1, B.1	1.0	1.0	No apparent change.	No apparent change.
C.2, B2	2.0	2.0	Slight browning at certain points on leaves.	No change.
C.3, B.3	4.4	2.0	Clearly defined spots or patches of brown tissue on all leaves.	Slight browning on two leaves.
C.4, B.4	21.8	2.0	Definite spotting, severe and uniformly distributed on all leaves.	Some browning, chiefly confined to regions damaged before immersion.
*C.1, B.1	1.0 23.1 24.1	1.0 4.6 5.6	Leaves showed numerous large brown patches.	Leaves showed few small brown patches.

* Two immersions.

Table III.—*The Extent and Course of Removal of Soluble Compounds from the Leaves of Cox's Orange Pippin and Bramley's Seedling by Cold Water as indicated by :—*

(*i.*) *Reduction in Dry Matter and Total Ash.* (*ii.*) *Amount of Potash* (K_2O) *in Extracts and Residues.*

1.	Analysis of Fresh Leaves.								
Variety.	Fr. wt. leaves.	Dry matter.		Ash.			K_2O.		
	grms.	grms.	as % fresh wt.	grms.	as % fresh wt.	as % dry matter.	grms.	as % dry matter.	as % ash.
Cox ..	19.15	6.45	33.7	0.379	1.94	5.85	0.1031	1.60	27.2
Bramley ..	19.72	5.86	29.7	0.353	1.77	6.03	0.1011	1.73	28.64

2a.	Analysis of Extracted Leaves (Whole).								
Variety.	Original fresh wt. leaves.	Dry matter in residue.		Ash in residue.			K_2O in residue.		
	grms.	grms.	as % original fresh wt.	grms.	as % fresh wt.	as % dry matter.	grms.	as % dry matter.	as % ash.
Cox ..	20.20	4.68	23.17	0.1245	0.62	2.66	0.0003	0.064	0.24
Bramley ..	20.00	4.31	21.55	0.1479	0.74	3.43	0.0151	0.350	1.02

2b.	Analysis of Extracts :—K_2O Determinations.									
Variety.	First 24 hours.		Second 24 hours.		Third 24 hours.		Fourth 168 hours.		Total period.	
	K_2O grms.	K_2O as % of total K_2O.	K_2O grms.	K_2O as % of total K_2O.	K_2O grms.	K_2O as % of total K_2O.	K_2O grms.	K_2O as % of total K_2O.	K_2O grms.	K_2O as % of total K_2O.
Cox ..	0.0684	64.05	0.0267	25.00	0.0061	5.71	0.0053	4.96	0.1065	99.72
Bramley ..	0.0132	11.90	0.0173	15.60	0.0223	20.11	0.0430	38.77	0.0958	86.38

3a.	Analysis of Extracted Leaves (Crushed).								
Variety.	Original fresh wt. leaves.	Dry matter in residue.		Ash in residue.			K_2O in residue.		
	grms.	grms.	as % fresh wt.	grms.	as % fresh wt.	as % dry matter.	grms.	as % dry matter.	as % ash.
Cox ..	20.2	4.09	20.25	0.1237	0.61	3.02	0.0040	0.98	3.23
Bramley ..	20.0	4.18	20.90	0.1478	0.74	3.54	0.0073	1.75	4.95

3b.	Analysis of Extract (Crushed leaves) :—K_2O Determinations.	
Variety.	K_2O extracted.	
	weight. grms.	as % total K_2O.
Cox	0.1121	96.55
Bramley	0.0983	93.20

B.—Experiments with Shoots Bearing Healthy Leaves.

TABLE IV.—*The Effects of Repeated Immersions in Water and Subsequent Exposures to the Air on Attached Leaves of Cox's Orange Pippin and Bramley's Seedling.*

Date.	No. of Immersion.	Times of Immersion.	Times of Removal.	Time Immersed. Hours.	Time Exposed. Hours.	Observations after the successive exposures.	
						Cox.	Bramley.
12 viii. 24	1	11.0 a.m.	12.0 a.m.	1.0	0.75	Lower leaves slightly spotted to ninth leaf from base of twig.	Only lowest leaf damaged. One spot, which appeared near a previous damage.
	2	12.45 p.m.	2 p.m.	1.25	1.0	Spotting on leaves from base to tenth leaf. Severe on leaves three—six.	No spotting except on lowest three leaves—very slight.
	3	3.0 p.m.	5.0 p.m.	2.0	1.0	Spotting present on all leaves though only slight on leaves nearest the apex.	As above.
12 viii. 24. 13 viii. 24.	4	6.0 p.m.	10.0 a.m.	16.0	1.50	Spotting on all leaves. Severe on terminal leaves. Spots small and evenly distributed.	Slight spotting on lower leaves. Terminal leaves free from spots.
Totals ..	—	—	—	20.25	4.25		

TABLE V.—*The Extent and Course of Removal of Soluble Compounds from Attached Leaves of Cox's Orange Pippin and Bramley's Seedling by Cold Water as indicated by :—*

(*i.*) *Reduction in Dry Matter and Total Ash.* (*ii.*) *Amounts of Potash* (K_2O) *in Extracts and Residues.*

1	ANALYSIS OF FRESH LEAVES.								
VARIETY.	FRESH WT. LEAF BLADES	DRY MATTER.		ASH.			K_2O.		
	grms.	grms.	as % fresh wt.	grms.	as % fresh wt.	as % dry matter.	grms.	as % dry matter.	as % ash.
Cox ..	23.57	7.89	33.16	0.4910	2.08	6.23	0.1792	2.27	36.49
Bramley ..	18.13	6.43	35.47	0.3158	1.74	4.91	0.1002	1.56	31.72

2	ANALYSIS OF EXTRACTED LEAVES.							
VARIETY.	FRESH WT. LEAF BLADES	DRY MATTER IN RESIDUE.		ASH IN RESIDUE.			K_2O IN RESIDUE.	
	grms.	grms.	as % fresh wt.	grms.	as % fresh wt.	as % dry matter.	grms.	as % of total K_2O obtained.*
Cox ..	—	5.11	—	0.1453	—	2.84	0.0063	3.0
Bramley ..	—	5.57	—	0.1860	—	3.34	0.0333	24.77

3	ANALYSIS OF EXTRACTS :—K_2O DETERMINATIONS.									
VARIETY.	First :—24 hours.		Second :—24 hours.		Third :—24 hours.		Fourth :—168 hours.		Total periods.	
	K_2O grms.	K_2O as % total K_2O.	K_2O grms.	K_2O as % total K_2O.	K_2O grms.	K_2O as % total K_2O.	K_2O grms.	K_2O as % total K_2O.	K_2O grms.	K_2O as % total K_2O.
Cox ..	0.0374	17.81	0.0579	27.57	0.0519	24.72	0.0565	26.90	0.2037	97.00
Bramley ..	0.0132	9.82	0.0178	13.24	0.0204	15.18	0.0497	36.98	0.1011	75.22

* The word " obtained " is here used advisedly as indicating the amount of K_2O contained in the extracts plus that contained in the leaf residue after extraction. It is possible that a certain amount of the K_2O obtained in the extracts in these experiments was extracted from portions of the immersed shoots other than the leaf blades.

The appearance of the leaves during and after immersion in water.

On immersion of leaves in water it was noted after a certain period that spots or patches of the leaf tissue soon presented a darker green appearance. On removal of the leaves, these spots either disappeared or turned brown according to the time of immersion. The time required for the development of the brown stage varied considerably for the two varieties employed. The deeper green appearance of portions of the tissue immersed was due to the injection of intercellular spaces with water, and if the leaf was removed in time this excess water dried out without visible damage to the cells. The browning of injected regions only occurred on exposure after longer periods of immersion and increased in extent with each successive immersion. Injection occurred readily through portions of the leaves damaged by folding and also, from the appearance and position of the spots, seemed to occur through the stomata.

Nature of the extracts obtained.

In the experiments in which successive extracts were poured off from immersed leaves, it was invariably found on filtering that these extracts readily clogged an ordinary filter paper and filtration was very slow. Though the extracts appeared quite clear, this fact suggested the presence of some colloidal substance such as pectin (3). During evaporation, the filtrates obtained always turned brown, indicating the presence of enzymes in the solution. In the final stages of evaporation over the waterbath, the characteristic smell of "apple-jelly" was always noted and the residue was of a golden brown syrupy nature.

Discussion of Experimental Results.

(*a*) *Qualitative observations.*

The results summarised in Tables II. and IV., together with the observations recorded in the foregoing section, show that it is possible to produce a form of spotting on the foliage of apples by successive immersion in water and exposure to the air. The experimentally produced "spot" differed from that occurring in the field in several features. The purplish discolouration of surrounding tissues was not observed in the experiments neither was the purple spot stage which precedes the initial breakdown of leaf tissue noted. The non-appearance of these symptoms may perhaps be accounted for by the greater rapidity of the process under experimental conditions. The conditions for the production of this leaf damage in the field and in the laboratory are in many respects comparable, though differing widely in degree of severity. It is possible in the field for exposed leaves to be completely wetted by rain, especially if rain is accompanied by strong winds as was frequently the case during the past season. Under such conditions, a leaf may be covered with a film of water for a period of several hours. Furthermore, in continuous rain, this film of water is being constantly replaced, so that

virtually the leaf surfaces are subjected to running water. The condition is thus comparable with one of immersion in that a large volume of water comes into contact with the leaf. Injection of the leaf is also possible in the field where wind damage and excessive rain occur together and experimental results show this to be responsible for considerable death of the tissues.

The results obtained with the two varieties employed agree well with plantation observations which indicated that the Bramley leaf was much more "resistant" than was the leaf of Cox. Whether detached leaves or whole shoots were used, spotting appeared on the leaves of Cox on exposure to air after approximately two hours' immersion in water, while a similar effect was only produced on Bramley leaves after an immersion of twenty hours.

(*b*) *Quantitative data.*

The results obtained in Experiments 2 and 4, summarised in Tables II. and V., show that substances may be removed from apple leaves by immersing them in cold water. A comparison of the figures obtained in analyses of leaf samples before and after immersion in water shows clearly the extent of this removal. Thus in the experiment with detached leaves (Exp. 2), over the total period of immersion, approximately 26 per cent. of the dry matter constituents of the leaves of both varieties were removed. The dry matter extracted contained 67 per cent. of the ash constituents of the leaves in the case of Cox and 58 per cent. in the case of Bramley. Determinations of the amounts of potash extracted together with determinations of the amounts contained in the leaves at the end of the experiments showed that 99.7 per cent. of the total potash was removed from the leaves of Cox, and 86.4 per cent. from those of Bramley.

The rates of removal of potash from the leaves are indicated by the results of analyses of successive extracts. The figures presented in Table III. show that the removal from the leaves of Cox is considerably more rapid than from the leaves of Bramley.

Reference to Tables III. and V. shows that the same relation holds whether the leaves are attached to shoots or detached during immersion. The figures for Cox in the two experiments are not comparable as the source of material differed in the two cases, but there is close agreement in the results obtained with Bramley. These relations are clearly shown in Fig I.

Physiological considerations.

Immersion of a healthy leaf in water exposes the tissues to at least two processes which might possibly damage living cells.

(i.) A process of injection of intercellular spaces with water, leading to asphyxiation of the cells in the injected region.

(ii.) A process of lixiviation, or washing out of soluble cell contents.

These two processes are connected since death of injected tissues, following asphyxiation, aids the rapid removal of soluble substances by washing. But injection and death followed by removal of cell contents are not sufficient to account for the large amounts of soluble substances obtained in the extracts. In an experiment in which shoots of Bramley's Seedling were immersed in water, the leaves on removal after twenty-four hours showed only slight damage. The shoots were kept alive in water for several days after removal and remained healthy, except for the small damage produced by immersion, over the whole period. Analyses of the extract in which the shoots had been immersed and of a sample of the slightly damaged leaves after immersion showed that approximately 10 per cent. of the total potash contained in the leaves had been removed. The amount of dead tissue was quite inadequate to account for such a loss.

It is therefore clear that some other processes must be concerned and of these a process of lixiviation or leaching seems to be most likely. The outer walls of the epidermal layer of a leaf are not impermeable. Cuticular transpiration, i.e., loss of water which may occur even when the stomata are closed, the presence of mineral salts in the cuticle, and the presence of silica deposits on the outer surfaces of such plants as the horsetails (*Equisetum*) and the grasses are sufficient proof of the permeability of the outer protective layer to water and dissolved substances. When a leaf is immersed in water a process of dialysis will go on whereby diffusible substances will pass through the permeable outer layers into the water. The rate and extent of this removal will depend on the degree of permeability of the surface layers and the nature of the dissolved substances present in the leaf tissues.

Potassium salts diffuse readily, (2), a fact which probably accounts for their practically complete removal from living tissues as shown in the case of the experiments recorded here and those of other workers (1), (4). Evidence that the permeable surface layer controls the passage of dissolved substances from the leaf is afforded by the experiment with crushed leaves. The results presented in Table III. (3a and b) show that approximately 95 per cent. of the total potash was removed from crushed leaves of either variety by twenty-four hours immersion. When the leaves were immersed whole, only the undamaged outer surfaces coming in contact with the water, Cox leaves lost 64 per cent. of the total potash, while Bramley leaves lost 12 per cent. in a period of twenty-four hours. These large differences can only be interpreted as indicating :—

(i.) that the outer surface layer controls the loss of dissolved substances from the leaf.

(ii.) that the degree of this control varied with particular varieties of apple.

PART II.

The results of the foregoing experiments, showing that soluble compounds were leached from apple leaves by immersing them in water, suggested that a similar process might operate under natural conditions in the field. If this be so it should also be possible by this method to compare the resistance offered by different varieties to this leaching action. To test these two points, experiments 5 and 6, were performed and these are described below.

EXPERIMENTAL.

Exp. 5. Leaves of Cox's Orange Pippin were collected from trees showing various stages of foliage damage on September 6th. Samples of approximately 20 grams each were collected as follows :—

Sample 1. Healthy leaves showing little or no discolouration.

Sample 2. Leaves showing purple spots or blotches but no dead tissue.

Sample 3. Moderately spotted leaves with some dead tissue.

Sample 4. Severely spotted leaves with much dead tissue.

The samples were dried to constant weight, ashed and the total potash (K_2O) in the ash determined as in previous experiments. The results of the analyses are presented in Table VI.

Exp. 6. To compare the difference in resistance to leaching of the leaves of various varieties of apples, healthy shoots were collected on August 13th from trees of the following varieties :—Bramley's Seedling, Allington Pippin, Worcester Pearmain, Newton Wonder, James Grieve and Cox's Orange Pippin. The procedure followed was similar to that employed in the earlier experiment (Exp. 4), with shoots of Cox's Orange Pippin and Bramley's Seedling.

The results obtained are summarised in Table VII. and graphically represented in Figure II.

EXPERIMENTAL RESULTS.

See Tables VI. and VII., pp. 158 and 159.

DISCUSSION OF EXPERIMENTAL RESULTS.

It is clear from the results presented in Table VI. that during the course of leaf damage to Cox in the field certain of the ash constituents are removed from the leaves. Potash determinations indicate that removal of potassium compounds occurs before actual death of the leaf tissues. Healthy leaves contained 36.5 per cent. of potash (K_2O) in the ash while the ash of discoloured leaves, in which breakdown of the tissues had not occurred, contained only

TABLE VI.—*Potash* (K_2O) *Contents of the Leaves of Cox's Orange Pippin at Various Stages of Damage.*

CONDITION OF LEAVES.	Wt. of leaves.	DRY MATTER.		ASH.			K_2O.	
	grms.	grms.	as % fresh weight.	Total grms.	as % of leaves fresh weight.	as % dry matter.	Total grms.	% of Ash.
Healthy	23.565	7.89	33.16	0.4910	2.08	6.23	0.1792	36.49
Purple Spot stage. (No dead tissue)	16.5	6.21	37.6	0.4707	2.85	7.58	0.1040	22.13
Moderately spotted. (With dead tissue)	20.0	8.74	43.7	0.6707	3.354	7.66	0.1323	19.73
Severely spotted. (With much dead tissue)	20.0	8.74	43.7	0.7826	3.913	8.96	0.1050	13.42

TABLE VII.—*The Extent and Course of Removal of Soluble Compounds from Attached Leaves of Several Varieties of Apple by Cold Water, as Indicated by ;—*

(*i.*) *Reduction in Dry Matter and Total Ash.* (*ii.*) *Amounts of Potash* (K_2O) *in Extracts and Extracted Leaves.*

VARIETY.	ANALYSIS OF FRESH LEAVES.						ANALYSIS OF EXTRACTED LEAVES.					ANALYSIS OF EXTRACTS.			
		Dry Matter.		Ash.	K_2O.		Dry matter.	Ash.	K_2O.			K_2O in Extracts as percentages of Total K_2O.			
	Leaves fresh weight grms.	grms.	as % fresh weight.	as % dry matter.	as % dry matter.	as % ash.	grms.	as % dry matter.	as % dry matter.	as % ash.	as % total K_2O obtained.	1st 24 hrs.	2nd 24 hrs.	3rd 24 hrs.	4th 168 hrs.
Cox's Orange Pippin ..	23.65	7.89	33.16	6.23	2.27	36.49	5.11	2.84	0.012	4.3	3.00	17.81	27.57	24.72	26.90
Allington Pippin	18.75	6.71	35.79	7.02	1.63	23.30	4.68	3.43	0.014	4.2	4.97	14.54	21.59	23.67	35.24
Bramley's Seedling ..	18.13	6.43	35.47	4.91	1.57	31.72	5.57	3.34	0.60	17.9	24.77	9.82	13.24	15.18	36.98
James Grieve ..	24.22	8.37	34.56	5.53	1.95	35.23	6.15	2.92	0.36	11.1	11.81	8.95	11.06	12.41	55.77
Newton Wonder	27.26	8.98	32.83	5.98	2.51	41.90	5.84	3.95	0.86	21.6	23.51	5.92	11.66	6.72	52.22
Worcester Pearmain ..	27.57	10.14	36.78	4.60	1.29	28.01	7.69	4.27	0.55	12.9	28.82	3.41	11.88	9.76	46.13

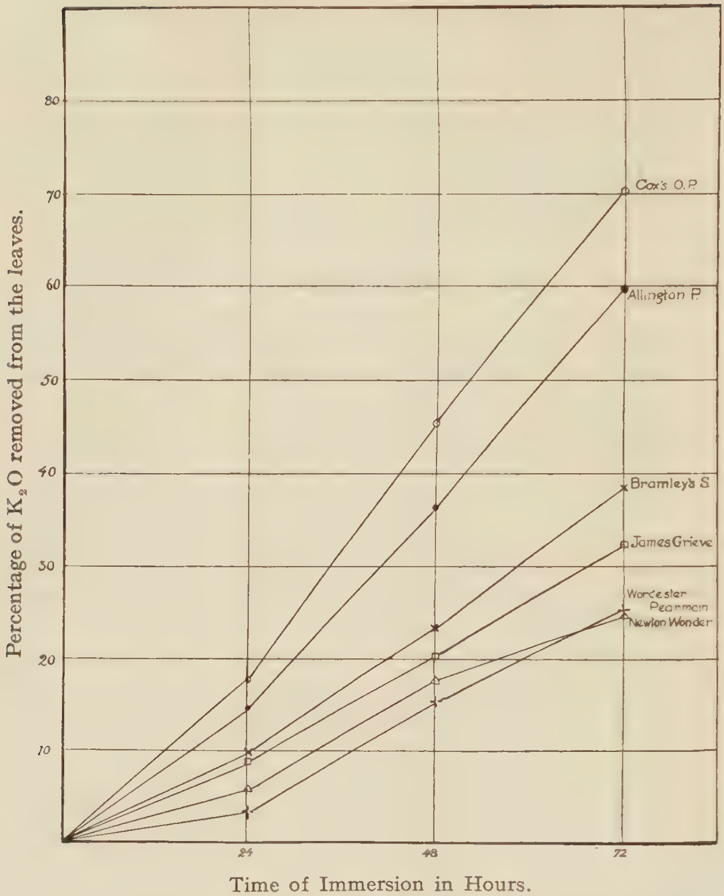

FIG. 2.—The course and extent of removal of Potassium compounds from attached leaves of different varieties of apple by immersion in cold water.

22 per cent. Loss of potassium compounds from the leaves precedes death and is not entirely consequent on the breakdown of the tissues. Either these compounds have been removed by some external process and are lost to the plant, or they may have passed from the leaves back to the plant internally. The fact that at the time damage occurred conditions were favourable for the passage *into* the leaves of large amounts of water and dissolved substances seems to send the balance of evidence in favour of the first suggestion, which is strongly supported by the experimental results recorded in Part I.

The rate of leaching, as indicated by the determination of potash in the extracts, is shown to differ between wide limits in the varieties investigated. The course of removal is the same in each case (Figure II.), which indicates that the same processes are operating throughout. It is clear that the leaves of

different varieties vary greatly in resistance. Also, it is significant that the two varieties on which spotting in the field was observed, namely, Cox's Orange Pippin and Allington Pippin, are the least resistant to the action of water. The analyses of the leaves of the varieties employed differ considerably in percentage dry matter, ash and potash. The differences obtained in the experiment should not be taken as strictly showing the order of resistance of the varieties. Before such an order can be determined it will be necessary to experiment with trees of the same age and on the same stocks under similar cultural conditions. Attention will be given to these points in future investigations.

SUMMARY.

(1) The behaviour of the foliage of certain varieties of apple trees when subjected to immersion in water and subsequent exposure to the air is described.

(2) A reduction in dry matter and ash constituents is shown to occur under the treatment.

(3) The course of removal of potassium compounds from the leaves is followed for several varieties of apples.

(4) The rate of removal of soluble constituents from leaves is partially dependent on the individual properties of the exposed surfaces and varies considerably with the variety of the tree.

(5) A comparison is drawn between natural conditions in the field and the conditions of experiment.

(6) Results obtained on the variety Cox's Orange Pippin indicate that potassium compounds are leached from the leaves under conditions occurring in the field.

(7) The work of previous investigators on the solubility of potassium compounds in plants is supported by results obtained with apple leaves.

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ON THE DISEASES KNOWN AS "BARK CANKER" AND "DIE BACK" IN FRUIT TREES.

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INTRODUCTION.

The term "Die Back" appears to be of American origin and according to Stevens and Hall (20) it was first used by Rolfs in 1907 to describe a disease of peach and Japanese plum trees in Missouri. The name "Die Back" was descriptive of some symptoms of the disease which was characterised by a wilting and killing of twigs and branches which commenced at the tips and progressed downwards to the larger limbs.

Considerable literature has accumulated on the subject of "Die Back" disease in different host plants as the result of work published both in England and abroad. The following is a *résumé* of the papers published by workers in England in the order in which they appeared.

As far back as 1902 Massee (15) described the disease occurring in nursery stock of Apple, Plum and Pear. He attributed the disease to the fungus *Eutypella prunastri* Sacc. and stated that he had obtained positive infections with the spores of the fungus. In the many specimens of diseased plants, belonging to different hosts, examined during the last eighteen months, the writer has found no trace of the fungus *Eutypella prunastri* Sacc.

In 1912 Wormald (23) published an account of the disease as it occurs in Cherry trees. He stated that although his observations suggested that *Cytospora* sp. was a parasite, they by no means proved it since inoculation experiments with mycelium and conidia from pure cultures are essential. His inoculation experiments with mycelium and conidia yielded negative results.

In 1915 Belgrave (1) described a disease or diseases of plum trees believed to be caused by one or more species of *Cytospora*. Inoculation experiments examined a year later showed no signs of infection.

In 1920 Wiltshire (22) working on the disease in plum trees, started to investigate the relationship between the bacterial masses and *Cytospora* sp. both of which he found present in the diseased tissues. At the same time he (21) described the Bark Canker Disease in Apples.

Three years later (1923) Miss Gilchrist (5) working on apple material from the same source, also described more fully the bark canker disease said to be caused by the fungus *Myxosporium corticolum* Edg.

Shortly afterwards, in July, 1924, Miss Cayley (2) published a very full account of " Die Back " disease as it occurs in stone fruit trees. Knowledge of " Die Back " in fruit trees in England was advanced very considerably as the result of Miss Cayley's work. For the first time the fungus *Diaporthe perniciosa* Marchal was described as being associated with, and said to be the cause of, " Die Back " disease in stone fruits in this country.

The most recently published work in this country on a " Die Back " in trees is an account by Day (3) of the Watermark disease of Cricket Bat Willow said to be caused by a short rod-like schizomycete which the author has provisionally called Bacterium salicis. The fungus *Cytospora* sp. is found closely associated with this disease but the author points out that the lowering of the physiological condition of the tree is undoubtedly necessary before this fungus can attack.

A boring beetle has also been found associated with the disease in the cherry and more often in plum. Field observations, however, show beyond doubt that this insect is late even as a follower of the primary cause or causes of this disease.

Of the foreign publications only those which are directly concerned with " Die Back " in fruit trees are referred to at this stage. Those dealing with " Die Back " in other trees will be referred to below.

In 1910 Rolfs (18) working at the Missouri Fruit Station, published an account of the Winter Killing of Twigs, Cankers, and Sunscald of Peach Trees. The organism mentioned in connection with the disease in Missouri is *Valsa leucostoma* (Pers.) Fr. var. *cincta* Rolfs.

In 1919 Stevens (19) described an apple canker in Illinois said to be due to *Cytospora.*

In 1921 Leonian (13) published his studies on the *Valsa* Apple Canker in New Mexico. As will be seen later, the *valsa* fungus with which this author worked is the same as the *Cytospora* studied by Stevens (19).

It will be observed that various organisms are said to be the cause of one and the same disease. Another striking fact is that in no case were inoculation experiments really successful in reproducing the main features of the disease. To produce local infections with one or more organisms inoculated into trees grown or treated unfavourably does not justify the statement that the organism—used for inoculation is the primary cause of disease.

It is not proposed to give detailed descriptions of the fungi *Myxosporium corticolum* Edgert., *Cytospora* sp., and *Diaporthe perniciosa* Marchal, in this paper since full accounts of these organisms have previously been given by Miss Gilchrist (5), Wormald (23) and Miss Cayley (2) respectively.

OBJECT OF INVESTIGATION.

In the United States (11) the fungus *Myxosporium corticolum* is responsible for the superficial bark-canker of the apple and the pear. The fungus mycelium grows in the outermost bark tissues only, and it does not reach the cambium. Its progress into the tissues is arrested by a layer of cork developed by the plant in response to the stimulation induced by the invading fungus. The affected tissue is killed and eventually it sloughs away. Fruiting bodies, acervuli, are formed just beneath the surface of the bark. The damage caused by the fungus is so slight that it is doubtful if any remedial measures are ever necessary or profitable.

Wiltshire (21) followed by Miss Gilchrist (5) working on a " Die Back " disease of apple trees came to the conclusion that it was due to *Myxosporium corticolum.* There is considerable difference between the disease as described by them and the Superficial Bark Canker of the United States, although the causal organism in both cases is the same. In England the wood is affected, whereas in the United States only the outer cells of the bark are affected, hence the name Superficial Bark Canker. To indicate this difference both Wiltshire (21) and Miss Gilchrist (5) called the disease Bark Canker, and omitted the word Superficial, since it did not apply in England. This has led to some confusion, since the disease in England is a " Die Back " and its cause, as will be shown later, is the same as " Die Back " in other fruit trees. The present paper has as its object the clearing up of the confusion between Superficial Bark Canker, Bark Canker, and " Die Back " in fruit trees, both in regard to the primary causes of the disease on different hosts, and the control measures to be taken against the disease.

THE DISEASE IN APPLE AND PEAR TREES.

The external appearance of the disease in apple trees is characterised by a longitudinal splitting on each side of an area of bark ½ to 1½ inches broad. The disease progresses very rapidly and in a few weeks the splitting of the bark may extend for the whole length of a main branch five to six feet in length (Plate V, Figs. 1 and 2). The disease may start at any portion of the branch and in one case developed on the trunk of the tree just above soil level. In the latter it caused the rapid death of the whole tree, whereas in the former individual branches are killed one after the other. In contrast with the extremely rapid advance of the disease in a longitudinal direction is its very slow development transversely. Girdling of a limb is very slow. The bark between the two longitudinal splits later becomes sunken owing to the skrinking of the underlying tissue and the cessation of growth of the wood in the affected region due to the death of the cambium. The wood underlying the sunken area of bark is

Fig. 1.

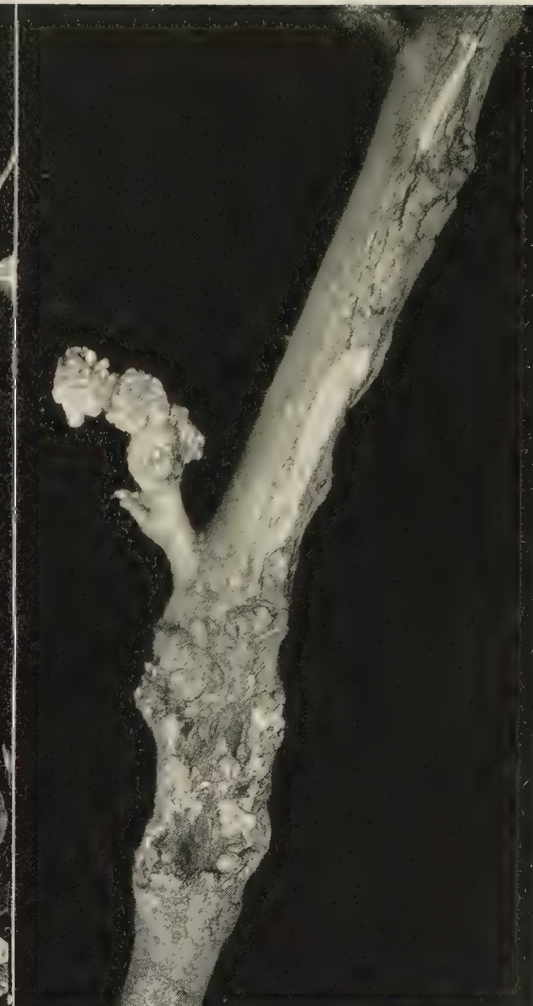

Fig. 2.

PLATE V.

Fig. 1.

Fig. 2.

PLATE VI.

brown in colour to varying depths up to half an inch or more. Microscopic examination shows the presence of fungus hyphae in the cortex, wood vessels, and medullary rays. As the bark is killed it invariably becomes covered with small raised black specks. These specks are the fructifications (acervuli) of the fungus *Myxosporium corticolum* Edgert. When mature a tiny slit appears in the bark at the centre of each speck. In moist weather the spores of the fungus (Plate VIII, fig. 2*d*) are liberated through the tiny slits and can be seen with the naked eye as white points. These are washed down the branches and trunks of the trees by rain. After the spores have been liberated, the acervuli appear as tiny, black, elongated, and shallow pits. As stated by Miss Gilchrist (4) the disease is active only towards the end of the summer. The symptoms and development of the disease on pear trees is similar to those on apple trees. The bark splits longitudinally and is always followed by the production of innumerable acervuli of the fungus *Myxosporium corticolum* Edgert. The underlying cortex and wood take on a brown discolouration and are invaded by fungus hyphae. In spite of the extremely regular occurrence of the fructifications of *Myxosporium corticolum* on the diseased bark of both apple and pear, it is difficult to regard this fungus as the cause of the disease. Over a dozen cultures have been made from time to time from the innermost diseased wood underlying the sunken bark of several affected branches and on no occasion has *Myxosporium corticolum* been obtained in cultures. The fungus which grows in cultures of such diseased wood is always *Diaporthe perniciosa* Marchal. Cultures from the outermost diseased wood yield generally a mixture of *Myxosporium corticolum* Edgert, and *Diaporthe perniciosa* Marchal. When the disease has advanced and the tissues are drying up pycnidia of *Diaporthe perniciosa* are often produced on the bark. Both *Myxosporium corticolum* and *Diaporthe perniciosa* produce conidia in culture. In the many cultures of *Diaporthe perniciosa* grown from diseased apple wood and the pycnidia on the bark which the writer has always found to contain " a " conidia only, the fungus generally produces pycnidia with " a " type of conidia only but in a few cases, both " a " and " b " types have been obtained in cultures made from " a " pycnospores. The " b " type as well as the " a " type are often formed by the fungus isolated from the plum, pear, and Cherry Laurel (Plate VIII, Fig. 2*a* and *b*). The " a " conidia of *Diaporthe perniciosa* resemble somewhat in shape those of *Myxosporium corticolum.* The former, however, are much smaller, being only 7-9 $\times$ 2-3 μ, whilst the conidia of *Myxosporium corticolum* measure 16-39 $\times$ 5-11 μ. The fungus *Myxosporium mali* Bres. mentioned by Miss Gilchrist has not been found by the writer. Mr. R. M. Nattrass and Mr. F. E. V. Smith have subsequently made cultures from the innermost diseased wood on apple and pear trees. As with the writer the fungus was found to be *Diaporthe perniciosa* Marchal. In view of the results obtained by culturing the underlying wood Mr. Smith

and the writer together made a detailed examination of the bark of apple and pear trees in the plantations at Long Ashton. They found that *Myxosporium corticolum* occurs on the bark of all varieties of otherwise healthy apple and pear trees which are twenty or more years old. Subsequent examinations of apple and pear trees throughout the western counties also showed that *Myxosporium corticolum* is always to be found on the bark of older trees.

SUPERFICIAL BARK CANKER.

The fungus *Myxosporium corticolum* as it occurs on the bark of otherwise healthy trees, agrees with the above description of the Superficial Bark Canker (11) and (24) in the United States. The fungus attacks the outer bark of the trunk and larger limbs generally, but sometimes occurs on the damaged bark of the younger branches. The disease can be recognised at some distance by the reddish or bronze colour and the slightly sunken appearance of the portion of bark attacked. The affected areas range in size from small areas of a few millimetres only in diameter to large patches measuring several inches across. These patches often coalesce and eventually the whole trunk is covered, so that it is extremely likely that the normal roughening of the bark in mature apple and pear trees in this country is due, in great part, to the activities of this fungus. Affected areas become covered with the innumerable fructifications of the fungus (Plate VI, fig. 1). The fungus hyphae never penetrate beyond the few outer layers of the bark cells, and as is found in America, it never reaches the cambium. The affected layer of bark is separated from the healthy by cork cambium which afterwards becomes suberised. Later, the outer bark can be easily peeled off with the hand. As a disease it does not warrant consideration by the grower and it is questionable whether the fungus is not, in some cases at any rate, beneficial since it gives the softer tissues underlying the outer bark a chance to expand in growth, thereby lessening the danger of the tree becoming bark-bound. Growth splits which occur in branches and trunks of trees in some seasons often become infected with *Myxosporium corticolum*, but its activities are confined to the outermost layers of bark. This stimulates the tree to the formation of corky tissue underneath and this quickly closes a wound which otherwise might be open to infection by a serious fungus parasite such as the silver leaf organism (*Stereum purpureum*), or the canker fungus (*Nectria galligena* Bres.). Cases of infection of growth splits by the latter fungus have been observed.

The following infection experiment on apple trees using *Mxyosporium corticolum* and *Diaporthe perniciosa* separately, and together, as inocula has been carried out. The variety of apple trees used was James Grieve. In all cases a slit in the bark and wood was made with a sterilised scalpel, and mycelium from pure cultures of the fungi was introduced with a sterilized needle and the

wound was then bound with raffia. Six trees were selected and six branches of each used for the experiment. Five branches of each of the trees were inoculated and the sixth branch served as a control in each case. The branches of two of the trees were inoculated with *Myxosporium corticolum:* the branches of two others were inoculated with *Diaporthe perniciosa:* and the branches of the remaining two with mycelium of both *Myxosporium corticolum* and *Diaporthe perniciosa*. The two fungi were used together because, at the time, it was thought that possibly one of the two fungi paved the way for the other, although any one of the two alone could not produce the disease. None of the inoculations succeeded in producing symptoms of the more serious disease of "Die Back," formerly known as Bark Canker, which is characterised by the longitudinal splitting of the bark. In almost every case including the controls and those inoculated with *Diaporthe perniciosa* only, fructifications (acervuli) of *Myxosporium corticolum* developed on the injured portion of the bark. This infection experiment gave negative results in spite of the fact that inoculations were made at the end of August, 1923, at which time of the year the disease commences to become active again. The negative result of this experiment is very significant. Observations of the disease as it occurs in the field show that in all cases where the disease occurs on apples and pears, the trees are in an unhealthy condition from some cause or causes before infection by *Diaporthe* can take place.

THE DISEASE IN STONE FRUIT TREES.

As in the case of apple trees the symptoms of the disease vary according to the point at which the disease commences. If it starts at a wound on a branch the same longitudinal splitting and sinking of the bark is noticeable, particularly in the plum, although the bark does not split to anything like the same extent in stone fruit trees as in apple trees. In all the host plants callus is formed by the healthy tissue bordering on each side of the sunken area of diseased tissue. The bark of the diseased area takes on a reddish colour and eventually becomes covered with the fructifications of *Cytospora* sp., or *Diaporthe perniciosa*, or more commonly with a mixture of both, particularly in the plum. Where extensive bark splitting does not occur the branches become somewhat flattened on one side. This is due to the cambium being killed on one side, and therefore further production of wood at this region is impossible, whereas growth continues in the unaffected portion of the branch. The splitting of the bark is usually accompanied by an exudation of gum. The wood, below the sunken area of bark is brown to more or less an extent depending on the degree to which the disease has developed.

Microscopic examination shows the presence of gum in the tissues, particularly the wood vessels and medullary rays. Fungus hyphae may or may not be found present in the vessels of the wood. It has been observed that

vessels whose cavities are completely filled with gum or tyloses do not contain fungus hyphae. This is so marked that it strongly suggests that fungus hyphae cannot penetrate readily through the gummy substance. Wound gum is probably, therefore, a deterrent to fungus infection. Branches and trunks of trees of all ages are subject to the disease. In the case of young trees which are generally attacked in the main stem the fungus *Diaporthe perniciosa* usually gains entrance at the point of union of stock and scion, and sometimes through a large and incompletely healed wound. The disease girdles the stem and the tree dies from below upwards. In the field generally the first noticeable sign of the disease is the sudden browning and wilting of the leaves in midsummer and soon afterwards the tree is killed. Later, the diseased areas become covered with fungus fructifications. These often develop whilst the branch or tree is still alive provided the disease is confined to one side only. If the branch or trunk is completely girdled fructifications appear after the tree has been killed. Several organisms are found in association with the disease on stone fruit trees. These include the fungi *Cytospora* sp., *Diaporthe perniciosa*, and in the case of few of the plum trees examined *Myxosporium corticolum*. In the case of one plum tree about eight years old the fungus *Cryptosporella prunicola* Oud. was found. The identification of this fungus was made for the writer by Miss E. M. Wakefield at Kew. Owing to the fact that the perithecia of this fungus were found very closely associated with the pycnidia of *Cytospora* sp. it was at first thought that it might be the perfect stage of *Cytospora* sp. Cultures of both, however, proved beyond doubt that this was not the case. Only the perithecial, stage of *Crytosporella prunicola* Oud. were found. Masses of rod-shaped bacteria which agree with those described by Wiltshire (21) are also found in the plant tissues. These bacteria are generally confined to the area between the healthy and diseased tissues and are exuded as light yellowish beads when the overlying bark is pressed with the thumb. As previously stated, it is at these points that the splitting occurs. What appear to be the same bacterial masses occur in peach and cherry as well as in the plum. Attempts to grow the bacteria in pure culture on artificial media have failed. These bacteria have not been observed on apple, pear or Cherry Laurel suffering from the disease. The only organism which is constantly present in diseased tissue in all host plants is *Diaporthe perniciosa*. On young plum trees the fructifications of *Diaporthe perniciosa* are generally confined to within a few inches of the area whence the disease started which in the majority of cases is low down on the stem at a wound or the point of union of stock and scion. The main stem above is covered with the fructifications of *Cytospora* sp. Plate VII, figs. 1 and 2 shows the same disease as it occurs in the Cherry Laurel (*Prunus Lauro-cerasus*). Portions of the sunken area of the bark of the Cherry Laurel were carefully incubated and examined for fungus fructifications and the only ones found were the pycnidia

of *Diaporthe perniciosa*. Both Mr. Nattrass and the writer made several isolations from the diseased wood and except where contamination by species of Penicillium occurred all yielded pure cultures of *Diaporthe perniciosa* to the exclusion of *Cytospora* sp., *Myxosporium corticolum* and bacteria. From the above it seems more than likely that, under certain conditions, the fungus *Diaporthe perniciosa* can produce the disease in all the host plants mentioned without the aid of bacteria, *Myxosporium corticolum* or *Cytospora* sp. On the other hand, the writer considers that although the fungus *Cytospora* sp. is a weaker parasite than *Diaporthe perniciosa* it, nevertheless, is sometimes independently, but more often following *Diaporthe perniciosa* a contributing factor in the killing of the plant. Furthermore, the evidence of this paper proves that *Diaporthe perniciosa* although the stronger of these two, is, nevertheless, also a weak parasite and cannot infect a healthy tree, but only those seriously enfeebled by one or more factors such as those discussed below. The general impression of the writer is that the bacteria are not pathogenic, but their presence cannot be entirely ignored. If at some future date they are proved to be weakly pathogenic it will make no difference to the conclusion drawn in this paper.

Evidence of Weak Parasitism of Diaporthe Perniciosa.

On Apple Trees.

The row of apple trees (James Grieve) on which the disease has mostly been studied by Wiltshire (21), Miss Gilchrist (5) and the writer, are twenty years old, planted ten feet apart with the same distance between the rows, and main branches are covered with large *Nectria* (Plate V, fig. 2) and Scab cankers, as well as American blight. Furthermore, the variety is a heavy cropper and the trees have, of late years, purposely not been freely manured. The trees were, in the first place, planted for intercropping purposes between standard orchard trees, but it was decided later to keep them as material for experimental purposes. The fruit and leaves borne are small in size for the variety, which is another clear indication of lack of vigour. Wiltshire (21) also remarked on the poor condition of these same trees. Some of the branches have been cut back from time to time and have become infected with *Diaporthe perniciosa* which under these conditions is capable of becoming a serious parasite. There was not sufficient vigour in the trees to push out the dormant buds below the point to which the branches were cut back. Had the trees been able to do this, the probability is that, they would not have contracted the disease to any serious extent. The disease has also been observed elsewhere on pear trees about twenty years old which were completely neglected during the war, and are badly attacked by both canker (*Nectria ditissima*) and Scab (*Venturia pirina*). During the war no cultivation of any kind was done and since then they have received very little manure. Several young trees of different varieties were

pruned in the early spring of this year and since then they have been under close observation. In the normal course of events the pruned end dies back as far as the next bud below it. The great majority of these snags became infected with different fungi including *Diaporthe perniciosa* and *Cytospora* sp., but, nevertheless, the twigs did not as a rule die back further than the next bud. In rare cases the twig or branch died back to the second bud, and was infected to this point with *Diaporthe perniciosa*, *Cytospora*, and other fungi. The cause of this was invariably found to be due to damage of the uppermost bud. The trees in question were robust, and healthy plants which had been liberally and regularly manured. Similar observations have been made on fruit trees elsewhere. The disease never progressed further than the point at which a new shoot was formed. If *Diaporthe perniciosa* and/or *Cytospora* sp. are the primary cause of disease it is difficult to understand why they do not kill the branches after gaining entrance into the tissues.

Three young apple trees which had been growing in pots for three years were transplanted into the open in the spring of this year. Early in June, when the trees were in leaf they were given, with other foodstuffs, a dressing of sulphate of ammonia. One of the trees was inadvertently given too heavy a dressing with the result that the roots were damaged and a few days later the leaves turned brown and the tree was defoliated. The tree later put out a fresh crop of leaves, but before it had recovered from the drastic treatment of three years of pot life, a transplanting in the spring, followed by severe root damage due to the sulphate of ammonia, it contracted the disease described above (Plate VI, fig. 2). The disease did not appear in the other two trees which remained comparatively healthy.

Apple trees are subject to a dying back of twigs and branches said to be due to *Cytospora* sp. The writer has never found this form of "Die Back" disease except in cases of trees or individual branches enfeebled by some other disease or physiological disturbance.

On Plum Trees.

Early in the summer of 1923 two unusually tall standard plum trees (some of the stems 7 ft. 6 ins. in height) about nine years old, were sent to the writer from the Evesham district. The trees were dying, although the uppermost branches were still living and were bearing yellowish green leaves. Very little growth had been made in that year. The lower part of the main stems were dead and covered with pycnidia of *Cytospora* sp. and *Diaporthe perniciosa*. The roots were all brown, dead and water-logged. The condition of the root system suggested bad dainage. The trees were seen by Mr. Locke, Foreman of the above Station, who recognised the trees, on account of their exceptionally tall stems, as some he had planted some years ago in a low lying and badly drained

FIG. 1.

FIG. 2.

PLATE VII.

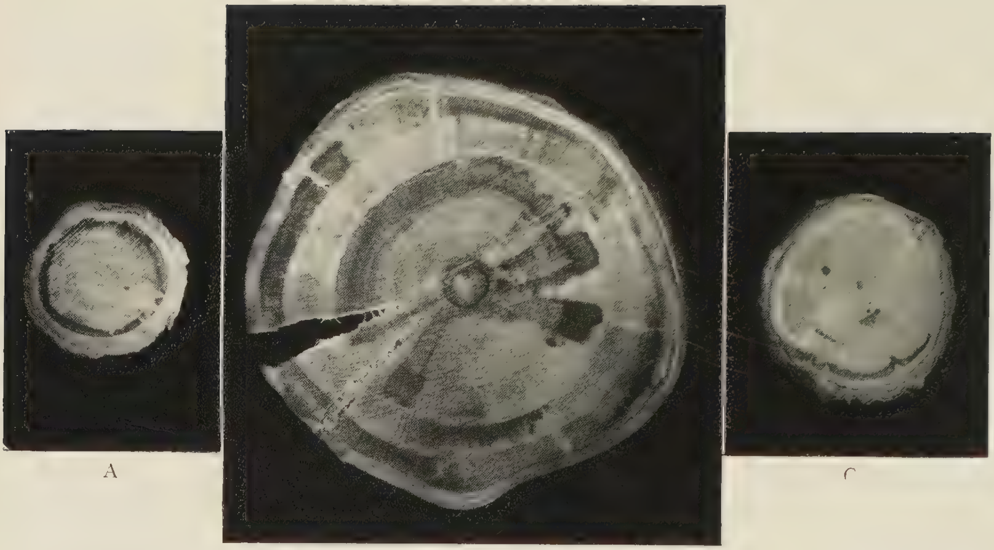

FIG. 1.

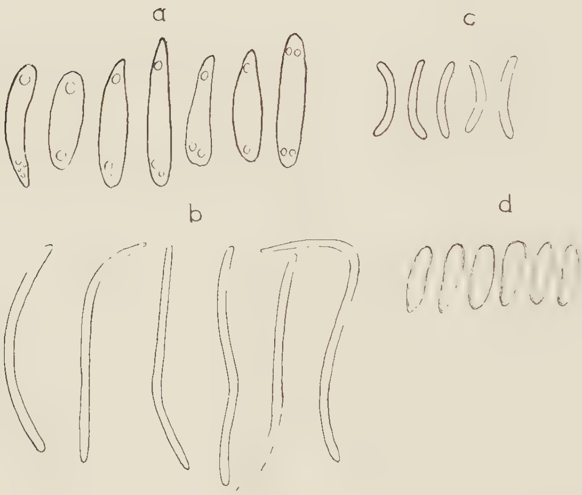

FIG. 2.

PLATE VIII.

orchard near Evesham. Mr. Locke states that, at the time of planting, he was convinced that they would not do well in that orchard. The soil in the orchard was later examined by the Station Soil Chemist, Mr. Wallace, who describes it as follows :—

> "A water-logged tract consisting of a surface layer of peaty material overlying a bed of impervious Blue Lias Clay."

The remaining plum trees in the orchard are not looking healthy and some show signs of infection by *Diaporthe perniciosa*. This is a clear case of trees, whose history is known, becoming enfeebled on account of bad drainage and killed by subsequent infection of *Diaporthe perniciosa*, followed possibly by *Cytospora* sp.

Plate VIII, fig. 1*a*, shows a cross section of the main stem of a young plum tree which was in a dying condition. The roots as in the above case were brown throughout. The tree was uprooted in the summer of 1923. The wood formed in 1923 is comparatively clean as compared with the deeply stained wood formed in the previous year 1922. The brown discolouration is due to the presence of gum in the wood vessels. Gum was present also in the medullary rays and cortical tissues. Discoloured wood of this kind is not invariably invaded by fungus hyphae. The browning of the wood is either the result of the reaction of the plant to the actual presence of hyphae at this point, or due to toxic substances produced by the fungus in tissues lower down on the stem and carried up through the vessels. In either case if the primary cause of the disease is due to infection by one or more fungi, or other organisms, it is more than probable that, after getting such a hold on the plant as to affect the wood formed during the whole of a growing season, the organism would have continued to do so in the following season. The only possible explanation is that the fungus is a weak parasite and its growth in the plant tissues has been checked in 1923 owing to a drastic change taking place in the environment of the plant. This in some cases is undoubtedly correlated with the amount of rainfall. Plate VIII, fig. 1*b* shows this very clearly. The cross section shown is of the main stem of a plum tree, one branch only of which was dead. The roots were examined and only one large root was found to be completely brown. The tree had been grown in the same position in the plantations of the Research Station, East Malling, Kent, for several years. The tree was, through the kindness of Mr. Hatton, cut down for examination in 1923. It will be seen that the disease had been present for some years. It is, significant, however, that during one year, namely 1921, the tree formed more and cleaner wood than in any other year. It is common knowledge that in the year 1921, the summer in England was exceptionally hot and dry. Plate VIII. fig. 1*c* is a cross section of the main stem of a young plum tree which again shows the seasonal activity of the disease.

Several plum trees have been examined and found to be in an advanced stage of the disease and the roots have been found on cutting to be clean and healthy looking. This was particularly so in the case of plum trees brought in from another fruit farm in the Evesham district. The trees were growing on light gravelly soil on a hill. In a normal year the soil dries out to a considerable depth in the summer. It is well-known as one deficient in potash and in consequence the apple trees in the plantation suffer from serious scorching of the leaves. Plum trees of seven or eight years old can be shaken from one side to the other with one hand. Unpublished experiments with willow cuttings by Wallace and Hutchinson at the above Station indicate that there are considerably more fibrous roots produced by plants growing in nutrient media containing potash than are produced by those grown in a medium deficient in potash salts. It is easily understood, therefore, that trees growing in gravelly soil deficient in potash cannot possibly produce a root system capable of absorbing sufficient moisture from a soil which is liable to dry out in summer. The general health of fruit trees can, therefore, be so seriously lowered, not only by excessive soil moisture due to bad drainage, impervious subsoil, etc., but also by insufficient moisture, whether this be due to the physical texture of the soil coupled with, or independent of, potash deficiency, as to make them susceptible to attack by the weak parasite *Diaporthe perniciosa* and possibly other organisms. So far as the root system of a plant is concerned the effect of a waterlogged soil and a soil too dry is physiologically very similar. In the first case waterlogging asphyxiates the roots so that they are unable to function as absorbing organs; in the second case the roots are possibly killed through excessive dryness and in any case they cannot absorb moisture from a soil which has become dessicated beyond a critical point. As already stated, the disease becomes active in the summer, but the pot plant damaged by sulphate of ammonia and alluded to above contracted the disease early in June after the second crop of leaves had appeared. The production of a second crop of leaves drained the shoot of its reserved food material which further lowered the plant's vitality and before it recovered as the result of leaf and root activities the plant contracted the disease. The progress of the disease in this plant was extremely rapid once it started. Miss Cayley (2) states, and Plate VIII, fig. 1*a*, *b* and *c* corroborates this view, that "infection occurs a considerable time—in some cases probably years—before any definite external symptoms can be seen; but that, once wilting has occurred, the affected areas die very rapidly. . . ." The reason for this is due in the first place to some physiological factor which upsets the metabolic balance of the tree so that *Diaporthe perniciosa* becomes parasitic. This infection further weakens the plant and usually the cambium is killed within a certain area. Progress of the disease is checked by change of conditions due to change of season or rainfall. The following year, or possibly longer, conditions again

become unsuitable to the plant and the fungus continues growth as a parasite. The rapidity of the advance made by the fungus depends on the degree of unsuitability of the conditions under which the plant grows. In the summer transpiration is at its maximum because the plant is in full leaf. The roots of trees growing in either too wet or too dry conditions from any cause cannot absorb sufficient to keep up the claims made on them by the transpiring leaves and the fungus under these conditions is able to kill further areas of cambium. The death of more and more cambium, and of wood in the same region, from year to year narrows down the conducting channels between root and shoots in an upward and downward direction. The effects of the primary and secondary (*Diaporthe perniciosa*, etc.) causes of the disease are therefore accumulative from year to year until a point is reached when the plant is so enfeebled that *Diaporthe perniciosa* can grow as a parasite much more rapidly with the result that the last stages of the disease are far more rapid than at the beginning.

Several plum tree branches were artificially infected with Silver Leaf (*Stereum purpureum*) for experimental purposes in the late summer of 1923. In the case of one tree a large branch contracted the " Die Back " disease in 1924, after the leaves had become silvered. Here is a case of the parasite *Stereum* weakening a branch to such an extent that *Diaporthe perniciosa* is able to cause a secondary disease. Mr. Nattrass informs the writer that he has observed similar cases elsewhere where Root Rot caused by *Armillaria mellea* was the first cause of disease.

On Young Plum Stocks.

The disease is often present in young stocks before any budding or grafting is done. An interesting and convincing case occurred at Long Ashton this year. The stocks (variety Blaisdon Red) were bought and planted out in rows in the autumn of last year. At the time of planting they were in a very poor condition, although there was no sign of " Die Back " disease present. In the spring of this year some of the plants failed to make any growth at all, whilst the others succeeded in doing so. Early in the year some of the failures were pulled up and thoroughly examined. The stem tissue was clean and healthy looking, but the stub below ground was brown and no sign of new root formation. Later in the summer another lot of the plants which had produced no growth were examined and found to have made no new roots. The stems were dead and the bark covered with fructifications of *Cytospora* sp., *Myxosporium corticolum* and *Diaporthe perniciosa*. Plate IX, figs. 1 and 2, shows the correlation between the extent of disease and the amount of shoot and root growth. This is a case where the development of the disease has been closely observed, and shows clearly that *Diaporthe perniciosa* and possibly other organisms came in as secondary factors. Plate IX, fig. 1, Nos. 2 and 4, illustrates the checking of the

"Die Back" at the point where new buds have grown out. Plate IX, fig. 2, No. 5, shows very slight development of roots coupled with the production of a feeble sucker and side branch.

The disease gets into young stocks as the result of rough handling and an unfavourable season or soil subsequent to transplanting from the stools or layers. The general practice is to dig up or rip up the young stocks and to heel them in before planting. The stocks take some time and often fail to recover, after planting, from this rough treatment, and *Diaporthe perniciosa* and possibly *Cytospora* sp. and other organisms in the meantime are a distinct source of danger. Where hundreds of thousands of young stocks have to be planted out there is a limit, for economic reasons, to the amount of attention that can be given in transplanting. However, it is far sounder to dig up the rooted stools rather than rip them up. In the former a considerable number of the roots are retained, whereas in the latter they are mostly destroyed. Before planting it is also advisable to go over each bundle and trim up the stub and shoots with a sharp knife, making good clean cuts. Further, it is obvious for a number of reasons that in heeling in care should be taken not to damage the root and shoot with hob-nailed boots.

Another source of danger is in budding and, if the latter fails, in grafting on stocks too soon. This operation, particularly grafting, which for other reasons is a bad practice, is an additional check before the young stock has become established after moving. In some nurseries the stocks, in preference to the scion, are carried up to form the stem in the case of standard and half standard trees. This is sound for three reasons: (i.) It gives the stock time to become thoroughly established. (ii.) The union of stock and scion will not be buried below soil level after leaving the nursery and put in their permanent position. (iii.) The union callouses over more completely and makes a straighter and therefore stronger stem than when budding or grafting is done low down on thick and oldish wood. There is a tendency for trees sent out of the nursery with poor root systems to be planted too deeply to ensure good anchorage. This is done in all classes of soil, and is a dangerous and bad practice in heavy land. Plum and other stone fruit trees should not be planted deeply especially in heavy, wet, and cold soils. Trees so planted take a long time to establish themselves in their new quarters since the whole of the root system must undergo a process of regeneration, and in the meantime *Diaporthe pernisiosa* is a source of danger. New roots must be produced higher up where conditions of moisture and aeration are most suitable for growth. Hatton, Grubb, and Amos (7) working with apple to investigate the effect of depth of planting on the growth of the tree, state that "(i.) the results depends to some extent on the variety of root stock; (ii.) seasonal variations affect the results; (iii.) the four or five inches difference in depth of planting give an obvious demonstration of the better anchorage of

the deeper planted trees." These three points are probably true of plum and other fruit trees and recommendation in regard to the earthing up of young stocks and the planting of young trees must be of a general character. It would be best in all classes of soil to plant as shallow as is compatible with good anchorage. These depths will, of course, differ for light and heavy soils. If the weather in the following growing season is too dry the plants can easily be earthed up. On the other hand, if the plants in the first place are planted deeply and the season is wet the soil cannot very well be removed without damaging the plants and they suffer in consequence. In other words, it is safer within reasonable limits to err on the side of shallow planting of young stock since in dry weather this can be rectified by earthing up.

On Cherry Trees.

Young cherry trees suffering from the "Die Back" disease were examined by the writer in the summer of 1924. The tops were still living and bearing leaves although in a very weak state. The root system was completely dead and brown. Subsequent inspection of the nursery proved the primary cause of disease to be a soil factor. The surface soil was light and sandy, and to all appearance favourable for growing cherry trees. Within six inches in some cases, and a foot in others, of the surface the soil consisted of a mixture of almost pure sand and small and large sand stones. The apple trees showed leaf scorch as well as the gooseberry bushes. There has been a certain amount of neglect in hoeing since a considerable number of roots were damaged and exposed above the surface of the soil. The soil was typical of those which are deficient in potash. The cherry trees still left in the nursery show no sign of "Die Back" disease (no fungus infection) since tests were made with the knife for diseased cortex. The leaves, however, were purplish and more highly coloured than is normal for the time of year, and in many cases the tissues between the veins were drying out. Here is another case where symptoms of abnormality are apparent before the advent of any weak parasite or parasites.

OCCURRENCE OF DIAPORTHE PERNICIOSA ON FRUITS.

So far as the writer is aware the fungus *Diaporthe perniciosa* has not been recorded previously in this country as a parasite in the orchard on any kind of fruit. This summer, however, a specimen of Peach fruit was received by the Advisory Mycologist for investigation. The fruit was attacked by a soft rot and on the outside of the rotted area there were innumerable fungus pycnidia. These were identified as *Diaporthe perniciosa* and the fungus was isolated from poured plates of the conidia as well as from the internal diseased tissue. At about the same time the writer collected in the plantation at Long Ashton a few undersized and rotting fruits on apple trees (var. Wellington or Dumelow's

Seedling). The fruits were attacked by Scab and a soft brown rot. The rotted portion was studded all over with the pycnidia of the fungus *Diaporthe perniciosa.* Poured plates of conidia were made and the fungus obtained in pure culture. Inoculation experiments through wounds were made on both Wellington and Bramley apples (Plates X, figs. 1 and 2). The fungus produced through a wound a soft brown rot and produced pycnidia (Plate X, fig. 2) on the fruit. *Diaporthe perniciosa* was again isolated from the innermost diseased tissue from the four inoculated fruits and a further inoculation and isolation proved the fungus to be pathogenic. No rot developed in the controls. Recently, diseased fruits of Medlar, sent for investigation, were found to be covered with pycnidia of *Diaporthe perniciosa.* The fungus was isolated from the diseased tissue, as well as from pycnospores. Whether or not the fungus is parasitic on Medlar fruits remains to be proved.

Further Evidence of Weak Parasitism of Organisms associated with the Same and Similar Diseases.

The following extracts from different publications by other workers on the same and similar diseases in trees strongly support the present writer's views in regard to the disease known as "Die Back" in this country with which the fungi *Diaporthe perniciosa, Cytospora* sp., and bacterial organisms are associated :—Leonian (13) in his account of an Apple Canker (*Cytospora leucostoma*) in New Mexico, concluded that old and neglected trees are the only ones which can be affected by this organism.

Long (14), working on a disease of Poplars in America, caused by *Cytospora Chrysosperma,* stated that the fungus is a serious parasite under conditions such as the following :—(*a*) On trees which are growing at the outer limit of their range and are therefore in a more or less unfavourable environment ; (*b*) On trees weakened from neglect and lack of sufficient water ; (*c*) On trees severely pruned as in pollarding.

Povah (17), who studied the same disease of Poplars in Syracuse, N.Y., states that *C. Chrysosperma* attacked Poplars weakened by fire.

Moss (16), who investigated the disease caused by *C. Chrysosperma* in Ontario states that :—"Younger trees of *Populus deltoides,* especially if seriously injured or weakened, are likely to succumb to the attacks of *C. Chrysosperma.*"

Rolfs (18), on Peach trees :

"The age and physical condition of the tree have a marked influence on the extent of injury done by the fungus. Young vigorously growing trees are not seriously injured by it. On the other hand, old neglected trees, especially those standing in sod, are sometimes permanently injured. The real source of danger lies in its attacks on weakened or injured trees, especially those injured by frost."

FIG. 1.

FIG. 2.

PLATE IX.

FIG. 1.

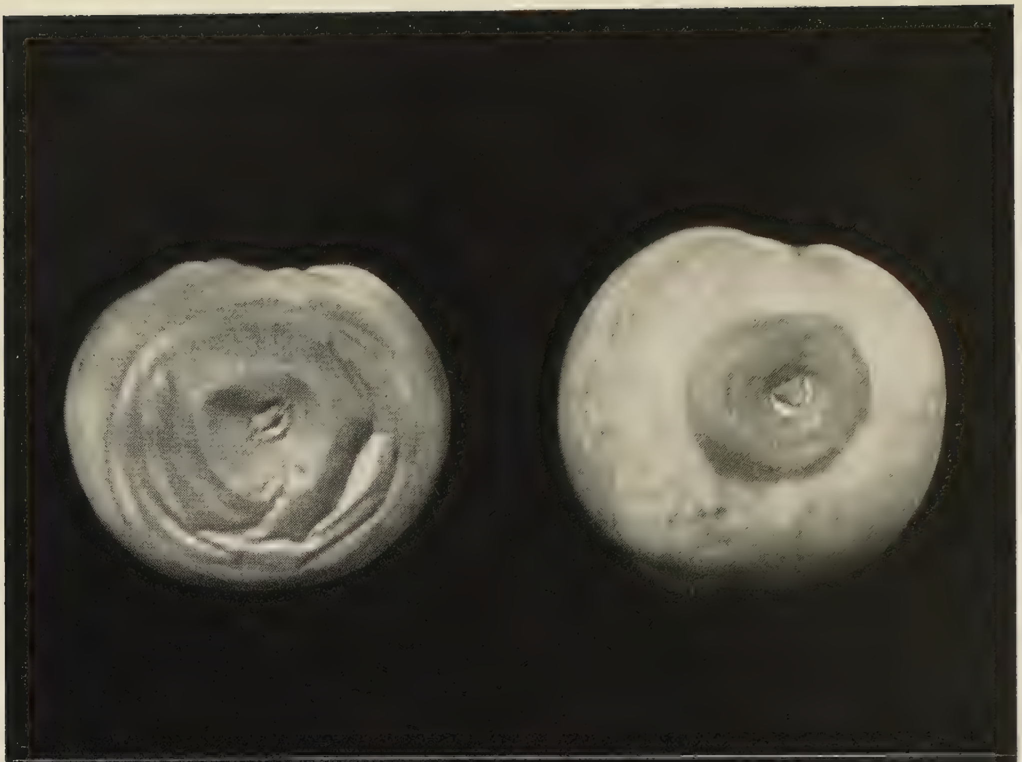

FIG. 2.

PLATE X.

"Frost, impoverished soil, wet land, lack of moisture, too deep planting, lack of cultivation, wind, fire, or anything which weakens or injures the tissues of the trees aid the organism more or less in its advancement."

Similar evidence can be obtained in the following papers :—Hubert (12), Hahn, Hartley, and Pierce (6), Hahn (7), Stevens (19), and Hemmi (10).

GENERAL CONSIDERATION.

It would appear that all or any of the organisms, including the fungi and bacteria which are found in trees suffering from "Die Back" disease, can only become pathogenic after the vitality of the tree has been lowered on account of some physiological disturbance, it is next important to consider what are the factors which cause these internal disturbances within the plant. Some of these have already been partly discussed, namely, excessive soil moisture and insufficient soil moisture. The relationship between soil moisture and the growth of plants is a big question and it cannot be fully discussed in the present paper. In England, however, as in other countries, the soil is very variable in character, not only in different districts, but often within a small area of an acre or less. Furthermore, the amounts of moisture in these different types of soils varies according to whether the season is dry, medium or wet. It is evident, therefore, that in soils which normally become very dry in summer, a wet season is advantageous to the plants growing in such soils. Those soils which are normally wet throughout the year improve so far as the plants are concerned if the summer is dry, as in 1921. In an abnormally wet year, such as the year 1924, soils whose moisture is normally within the range of the plant's tolerance become too wet and the plants suffer. Thus a dry season might check the progress of "Die Back" disease in some soils, whilst in others the disease progresses rapidly. Apart from the physical nature and condition of a soil—the growth of a plant is also dependent on the chemical nature of the soil. Some contain an excess or insufficiency of lime; others are deficient in available nitrogen, potassium, or phosphates. Excess or deficiency of any of these chemicals affect the general health of the tree to different extents. In some cases it is extremely difficult to decide what is the factor which affects the growth of the plant. In others the symptoms of the plant are helpful, e.g., Leaf Scorch, Chlorosis. A good many troubles can be avoided by judicious, regular and complete manuring, and a good many can be brought about by neglect of manuring or unbalanced manuring. It needs but little experience to recognise by the tree itself whether it is being overfed or underfed. In addition to carrying a good crop of fruit a tree should make a fair amount of new shoot growth. If this is not done then it is evident that manuring is necessary. On the other hand, if a fruit tree makes strong new shoot growth year after year and bears no fruit it is equally evident that the tree wants to be checked (e.g., by ringing, light pruning,

clamping, or transplanting) to throw it into a fruiting condition. The amount of manure to be given afterwards will be decided by the amount of fruit borne and the growth made. If unmanured fruit trees are allowed to bear heavy crops year after year very little new growth will be made, the fruit will be small and the general health of the tree is so lowered that sooner or later it will succumb to one or more diseases.

Most fruit trees are subject to attacks by insects and fungi and often conditions which favour one may suit the other. A well-known example of this in England is Brown Rot and Aphis attack on plum and other fruit trees. It is common knowledge amongst growers that a bad attack of Aphis and Brown Rot not only may cause complete loss of the crop in the year of attack, but also in the following year and possibly the next. The check to the trees is, therefore, of a very serious nature. During the period which elapses between the attack and recovery the tree is in a low state and it is extremely probable that organisms such as *Diaporthe perniciosa, Cytospora,* etc., can, under such conditions, cause further serious damage to the trees.

In some seasons some varieties of plum trees produce a second crop. This is an unusual procedure for plum trees, but an unusual behaviour of any plant is merely the usual reaction to unusual conditions. In other words, plants never do anything unusual or abnormal, strictly speaking, but are true to their habit by reacting to unusual conditions. Thus a tree does not produce a heavy single crop or a second crop because it is going to die or be weakened, but rather the cause of death or weakening is such that the normally behaving plant produces a heavy or second crop. A sudden, serious, but temporary check in the growing season sometimes causes fruit trees to bear a second crop. The production of this second crop drains the plant of its reserved food material which cannot possibly be replaced in the short period between the removal of this second crop and leaf fall and dormancy.

It is often desirable to head back trees, or to remove large branches for the purpose of thinning. Some kinds of fruit trees can withstand this form of treatment more than others. Nevertheless, there is a limit to which heading back can be done without affecting the health of the tree particularly when large limbs are roughly hacked off or cut through with a saw or other blunt implement (Plate VII, fig. 2). It is advisable after removing a branch with a saw to pare the cut end obliquely with a sharp knife or chisel. Branches should also be removed at the base close up to the mother branch or main stem. After paring off, such large wounds should be treated with a wound dressing all over and freshly pared again round the outside edge so that the inner bark (cambium) is left cleanly cut and in the best condition for quick callus formation.

Hatton (9) finds that different stocks affect the growth of the scion in different ways such as the following :—

(A) Some impart vigour. (B) Some have a slight dwarfing effect. (C) certain stocks accelerate the actual time of blossoming whilst others delay it. (D) under the conditions at East Malling some have a firmer anchorage than others. (E) Some stocks seem to show what is described as incompatabilities with certain varieties, whilst for other varieties they may be good stocks. In some cases either buds fail to make in any quantity or sometimes established trees break away at the point of union.

In view of these effects of different stocks on the growth and general behaviour of the scions worked on them, it is possible that a variety worked on one stock may be more susceptible to " Die Back " disease than others. This point is under investigation at the present time at Long Ashton. The remarks given above in regard to the views of some continental workers on cherry " Die Back," and the effect on time of blossoming found by Hatton (9) is extremely interesting. Some German workers, already mentioned, stated that late spring frosts was the pre-disposing factor to " Die Back " in cherry. It is possible that the use of stocks which delay the time of blossoming, in districts liable to suffer from late frosts might be an important factor in the extent to which the disease would occur under those conditions.

Control.

It is generally accepted that healthy vigorous trees are less liable to succumb to disease than those in a weak condition, but so far as " Die Back " disease is concerned a study of the conditions under which the plant grows is all-important before any treatment can be recommended. The predisposing cause may be due to any one or more of the factors mentioned above and these by no means exhaust the number which can bring about lack of vigour in fruit trees. Growers troubled with " Die Back " in their fruit trees are strongly advised to consult a specialist in the subject of plant diseases because by so doing they will often be able to avoid very serious losses in their plantations. It is futile to attempt to fight the fungus by direct methods once it has gained entrance into the plant. To remove dead and diseased tissue, if in the main stem and it usually is, means killing the tree. Even if it were possible to removed diseased tissue without killing the plant this would by no means cure the disease. On the other hand, the disease can, in the majority of cases, be prevented and checked by the elimination of the primary and fundamental cause or causes which predispose the plant to disease.

In conclusion I wish to express my thanks to Prof. Barker, Director of the above Station, for his constant and kind direction ; to Miss E. M. Wakefield of the Herbarium, Kew Gardens, for identifying and checking the identification of some of the fungi mentioned in this paper; to Dr. G. H. Pethybridge for his kindly criticism and helpful suggestions in regard to the arrangement of the

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Summary.

1.—The Superficial Bark Canker Disease known and originally described in America, and caused by the fungus *Mxyosporium corticolum* Edgert., is constantly present in this country on apple and pear trees twenty years old or more.

2.—The damage caused by it in this country is negligible and it does not require any treatment. There is even a possibility that, in some cases, the activities of the fungus are beneficial.

3.—The supposed Bark Canker Disease as described previously in this country and also attributed to *Myxosporium corticolum* Edgert. occurs only on trees which are already in a weak condition. It is in reality due to the weak parasite *Diaporthe perniciosa* Marchal, which becomes pathogenic only on trees already weakened by other causes.

4.—The fungus, *Diaporthe perniciosa,* is of common occurrence as a weak parasite on fruit trees, having been found to produce a form of "Die Back" in stone fruits as well as on the Apple and Pear. The Bark Canker Disease is the type of "Die Back" which is caused on the apple.

5.—The organisms found associated with "Die Back" of stone fruits are *Cytospora* sp., *Myxosporium corticolum* Edgert., *Diaporthe perniciosa* Marchal, and rod shaped bacterial organisms.

6.—There is strong evidence that none of these organisms is the primary cause of trouble, and that *Diaporthe perniciosa* and in some cases *Cytospora* sp. are weak parasites. The stronger of the two weak parasites in the majority of host plants, is *Diaporthe perniciosa.* Neither can cause disease in a sound and healthy tree and infection by either or both is only possible after the tree has become sufficiently enfeebled on account of one or more physiological factors, e.g., excessive or insufficient soil moisture.

7.—The disease, so far as present knowledge goes, cannot be satisfactorily controlled by direct action against any or all the organisms associated with the disease. It can, however, be prevented and checked by the elimination of the factor or factors which so enfeebled the plant as to render them susceptible to disease by weak parasites.

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Explanation of Plates.

Plate V.

Fig. 1. Upper portion of Apple branch (James Grieve) affected with "Die Back."

Fig. 2. Lower portion of same branch which shows that the "Die Back" is confined to the area above the large Nectria Canker.

Plate VI.

Fig. 1. Superficial Bark Canker (*Myxosporium corticolum* Edgert.) on main stem of standard apple trees.

Fig. 2. "Die Back" on young apple tree, showing acervuli of *Myxosporium corticolum* on bark of affected region.

Plate VII.

Fig. 1. Branch of Cherry Laurel with "Die Back." Cut end shows wedge shaped region of affected wood. Pycnidia of *Diaporthe perniciosa* on bark.

Fig. 2. Another view of same branch, showing the pruned end at which infection took place.

Plate VIII.

Fig. 1 (*a*, *b*, and *c*) shows the effect of season on the development of "Die Back" disease. Sections of Plum trees.

Fig. 2. (*a*) The "a" spores of *D. perniciosa* × 900.
(*b*) The "b" spores of *D. perniciosa* × 540.
(*c*) The pycnospores of *Cytospora* sp. × 1000.
(*d*) The conidia of *M. corticolum* × 300.

Plate IX.

Fig. 1. (1) Healthy plum stock (Blaisdon Red).

Fig. 1 (2, 3, and 4). Plum stocks (Blaisdon Red) showing various stages of "Die Back" disease. Note poor root systems.

Fig. 2. (5) Blaisdon stock very badly affected with "Die Back" disease.

Fig. 2. (6, 7, and 8) Blaisdon stocks killed by "Die Back" disease. Fructifications of *D. perniciosa* and *Cytospora* sp. on bark.

Plate X.

Fig. 1. Two Wellington (Dumlow's Seedling) apples artificially infected with *D. perniciosa*. 20 days after inoculation.

Fig. 2. Two Bramley's Seedling apples artificially infected with *D. perniciosa*. 20 days after inoculation. The fruit on left shows fructifications being produced.

THE PHYSICS OF SPRAY LIQUIDS.

IV.—THE CREAMING CAPACITY OF EMULSIONS—PARAFFIN SOLUTIONS.

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It is well-known that if small spheres of the same diameter are packed as closely as possible into a given space, the volume they will occupy is 74,048 per cent. of the total volume available, independent of the size of the spheres (1), provided no deformation of the spheres takes place. Pickering (2) draws attention to this mathematical limit, and found the ratio of oil to creamed emulsion to be between the ratios 65 : 100 and 82 : 100 by volume, independent of the initial ratio of the volumes of oil and aqueous phases shaken together to form the emulsion. He stood oil emulsions for twelve weeks and analysed (by "cracking" or "breaking"), the supernatant emulsions or "creams" which, in his experiments, invariably rose to the surface.

His work has been repeated by a different method ; known volumes of the oil and aqueous media were measured into stoppered graduated cylinders and shaken at intervals (3) till emulsification occurred. The cylinders were then allowed to stand, and the volume of cream was read off after the emulsion seemed to have creamed fully. The line of demarcation between the emulsion cream and aqueous underlayer was quite definite (2) and, because of the irregularities of the upper surface of the cream, it was found better in practice to arrive at the volume of cream by reading the volume of aqueous underlayer and subtracting from the total volume of aqueous plus oil media originally placed in the cylinder ; (no change in volume was noticed on emulsification in the case where the oil volume was, say, less than 50 per cent. of the total volume of both phases, so that on emulsification the whole emulsion was fluid when first made, and hence the upper surface quite readable).

Assuming that only negligible traces of oil were present in the aqueous underlayer, as evidenced by lack of turbidity, the ratio of the volume of oil (= volume of oil taken initially) to the volume of cream could be easily calculated.

Emulsions of toluene, benzene and paraffin oil in a 0.4 per cent. solution of Coignet's Gold Leaf gelatine were made ; the percentage of oil taken to the total volume of both phases varied from 0.7 to 83.3 per cent. in thirty-four different experiments. The more concentrated emulsions were made by the method of intermittent shaking, the oil being added gradually (3). The percentages by volume of oil in the creams which rose to the surface were calculated as above, and are given in Table A. :

Results of the same order were got by diluting the above emulsions with water or gelatine solutions and re-shaking, or by diluting the creams with water and re-shaking.

It will be seen that all the above emulsions, containing initially 0.7 to about 71 per cent. of oil by volume, give creams containing on an average 72.28 ± 0.67 per cent. by volume of oil, the actual range being 65.5 — 80.5 per cent. of oil ; emulsions containing about 75 per cent. of oil or over, initially, show no tendency to cream even on long standing ; on dilution, however, these concentrated emulsions give creams containing about 70 per cent. of oil by volume.

TABLE A.

Volume % of oil to total phases.	Volume % of oil in cream.	Volume % of oil to total phases.	Volume % of oil in cream.	Volume % of oil to total phases.	Volume % of oil in cream.	Volume % of oil to total phases.	Volume % of oil in cream.
0.70	70.18	35.09	73.87	66.67	72.06	66.67	71.42
0.70	70.18	35.72	70.42	66.67	72.73	66.67	77.66
1.35	67.57	36.23	72.46	66.67	73.38	66.67	77.66
14.28	65.58	36.23	80.51	66.67	73.38	71.43	72.46
16.67	67.57	50.00	67.57	66.67	72.06	75.00	all cream
16.67	76.92	66.67	70.18	66.67	76.19	80.00	do.
25.00	67.57	66.67	70.18	66.67	76.91	83.30	do.
28.57	74.02	66.67	72.06	66.67	79.20	—	—
35.09	70.18	66.67	71.42	66.67	67.56	—	—
		mean (excluding last 3 results) $=72.28 \pm 0.67$ mathematical limit $=74.048$					

In view of Ostwald's now discredited phase-volume theory of emulsions (1 and 4), it is interesting to discuss the significance of creaming of emulsions. According to Ostwald two types of emulsion are only possible over a certain range of concentration: thus an emulsion of one liquid in another is only possible when the volume concentration of the dispersed phase is less than 74 per cent.; the double series of oil-in-water and water-in-oil emulsions is therefore only possible over the range of 26-74 per cent. by volume of one liquid. The preparation of very concentrated emulsions (2) has been quoted as evidence against this theory.

All the emulsions dealt with by the writer and by all authors who have stated their experiments in detail (*e.g.* Pickering (2) and Holmes and Child (5), *etc.*) have shown this tendency to cream, if less than 74 per cent. of the internal phase be initially present. The time of creaming may be variable and may be a period of a few hours or one of months; this, of course, may depend on the viscosity of the emulsion, *e.g.*, raw milk creams rapidly, whilst homogenised milk creams slowly due to the large increase of viscosity dependent on the great increase of adsorption of calcium caseinate on the smaller fat globules (6); it may also depend on the equalisation of densities of the internal and external phases of the emulsion: if to emulsions of oil in soap solution a third liquid, soluble in oil to a larger extent than it is soluble in soap solution, is added, the third liquid having a greater density than the aqueous phase (and of course than the oil phase), then the rate of creaming of the emulsion is retarded; examples of this will be given in the next paper, some 1 per cent. emulsions of paraffin oil taking weeks to show the appearance of creaming.

It is probable that even the dilute so-called "stable" emulsions prepared by Lewis (7) show this tendency to "cream"; "creaming," of course, in the

case of these, would probably mean segregation of the phases or " breaking " of the emulsions, as no emulsifier is present.

Pickering (2), in speaking of emulsions of oil in soap solution states that " the whole of the liquid, however, is not an emulsion, properly so called, but a mixture of the emulsion with excess of soap solution ; on standing, the true emulsion separates and, if the substance emulsified is lighter than water, rises to the surface " and " generally contains 65-82 per cent. by volume of oil " the " line of demarcation between the emulsion and the excess of liquid " being well defined.

In view of the above, the writer is led to go further than Ostwald (4) and to express the opinion, which Pickering hints at in the quotations given but does not state, that there is only one *true* emulsion which can exist permanently, the emulsion being one containing 74.048 per cent. of internal phase by volume, and constituting the cream on so-called emulsions. The variable amounts of oil in the cream, as found by Pickering and the author, are probably due to the facts that the oil globules are not of the same diameter and are not perfectly spherical, and that the oil is probably soluble to differing extents in the aqueous external phase (8). So-called emulsions containing less than 74 per cent. of disperse phase would, if the disperse phase were present in perfectly spherical equal globules, cream to this true emulsion ; so-called emulsions containing more than 74 per cent. of disperse phase do so because of distortion of the disperse globules, and addition of more external phase with reshaking gives the true emulsion finally by creaming. Thus a so-called emulsion containing less than 74 per cent. of disperse phase is a *mixture* of this true emulsion and excess external phase, the latter draining out in time.

With regard to these so-called emulsions containing less than 74 per cent. of oil it is interesting to discuss the question of stability ; many writers infer that an emulsion mixture which creams very rapidly is necessarily very unstable. This may be true in some cases ; it is certain that rate of creaming has an effect on stability (due to concentration of disperse phase particles) in all cases, as will be shown later. It is erroneous, however, to assume that rapid creaming of an emulsion mixture indicates great lack of stability, for rapid creaming is usually due to the great difference in densities of the two phases.

For horticultural considerations, it is necessary to differentiate between the true stability, and the stability to creaming, of an emulsion mixture. An emulsion mixture which possesses true stability is one which shows no tendency to " crack " and give disperse phase in mass ; the stability to creaming is, of course, shown by the reluctance of the mixture to " cream " into the concentrated true emulsion and excess external phase. Of these two stabilities, that pertaining to creaming is of greater moment in the practice of spraying ; for an emulsion mixture used in horticulture will usually be stable for days, at least, before

showing definite signs of cracking, whilst creaming may be very evident a few minutes after preparation of the mixture.

That true stability and stability to creaming of emulsion are, to some extent, connected, can be shown by the following facts : Sobbe (9) proved that very little creaming took place in the case of homogenised milk, whilst raw milk creamed rapidly, *i.e.*, homogenisation increases the stability to creaming ; Briggs (10), by means of repeated homogenisation of hand-shaken emulsions, was able to increase greatly the stability of the emulsions. These two experiments seem to connect together inseparably true stability and stability to creaming ; but a consideration of the factors governing true stability indicate that this parallelism is brought about by a third factor of great importance, especially when homogenisation takes place.

Many factors influence the stability of emulsions. The interfacial force existing at the boundary surfaces of the two liquid phases tends to reduce the interfacial surface to make a more stable system (such a reduction, of course, meaning a lowering of free energy of the system) ; this reduction of surface can only be accomplished by coalescence of the particles of internal phase, and hence the existence of interfacial tensions may be said to oppose stability. As a direct consequence, a low interfacial tension is desirable when making stable emulsions.

The Brownian movement is also a factor opposing the stability of emulsions, for it tends to cause collision, and hence coalescence, of the adjoining liquid disperse globules. A third factor opposing stability is the coalescence of adjoining globules brought about by increasing concentration of the globules, *e.g.*, by formation of a " cream " ; this factor, of course, depends to a large extent on the relative densities of the two phases.

The existence of these three factors, as stated, opposes the stability of emulsions ; a factor conducive to stability is the electric charge on the globules of disperse phase, which tends to make the globules repel each other on near approach.

Homogenisation of a relatively coarse-grained hand-shaken emulsion means, besides a reduction in the size of globules with a consequent increase in Brownian movement (11), an enormous increase in the interfacial surface of the two phases, with a consequent increase in the free energy of the system ; both these effects tend to cause instability, and the question thus arises as to why a homogenised emulsion should be more stable than a coarse-grained one.

The interfacial tension of the two liquid phases must be low ; but if the two phases of the emulsion are separated only by liquid films of low interfacial tension, the Brownian movement and increasing concentration (such as is obtained on creaming), would cause coalescence of the adjoining drops. It is therefore generally accepted that a third important factor is necessary to cause stability, and this is the existence of a rigid adsorbed film or skin round the

globules of the disperse phase. These films are composed of small particles; thus the colloidal particles found in the pseudo-solutions of such protective colloids as soaps and gelatine are capable of adsorption at the interfacial surfaces of the liquid phases of the emulsion (thereby lowering the free energy of the emulsion system and causing greater stability) to form rigid protective films round the globules of disperse phase (12 and 2). Furthermore, it has been shown by Pickering (2 and 13) that many finely-divided solids act as emulsifiers and are capable of adsorption at the liquid/liquid interface to form this protective film, the chief characteristic of which must be rigidity. Adsorption of emulsifier is probably the greatest factor influencing emulsion stability.

On homogenisation of an emulsion mixture such as, for instance, milk, various factors governing stability are brought into play. The subdivision of the fat globules causes increased Brownian movement and increase in the interfacial surfaces, both effects tending to decrease stability; but since the number of fat globules has increased about a thousand times (6), the interfacial (or adsorbing), surface is increased enormously, with a consequent increase in the amount of calcium caseinate adsorbed at the liquid/liquid interfaces. Thus Wiegner (14) reduced the average diameter of the fat globules in a sample of milk from 2.9 μ to about 0.27 μ by homogenisation and, from viscosity measurements (basing his calculations on the assumptions that only casein was adsorbed, and that the thickness of the adsorbed layer is 6.8 $\mu\mu$), showed that, of the casein present in the milk, 2.27 per cent. was adsorbed at the interfaces in the case of the original, and 25.2 per cent. in the case of the homogenised sample. The great influence of the adsorbed layer in causing stability is shown by the fact that it is impossible to churn homogenised milk into butter (6 and 9).

The increased adsorption of caseinate in homogenised milk is apparent by the great increase in the viscosity of the milk on homogenisation, homogenised milk being visibly thicker than ordinary milk. The viscosity of an emulsion mixture has been shown by Hillyer (15 and 5) and others to itself be a factor governing stability, high viscosity tending to stabler emulsions. The greater stability to creaming of homogenised milk is probably due to the high viscosity of the system, which, in turn, is due to increased adsorption. Thus whilst increase in true stability of an emulsion mixture on homogenisation is mainly a direct consequence of increased adsorption of emulsifying agent causing reduction in the free energy of the system, and forming a rigid protective layer, increase of stability to creaming is probably only a secondary effect of increased adsorption, the greater viscosity thus caused making creaming more difficult. True stability and stability to creaming, though connected to some extent, should, therefore, be differentiated, especially in the case of hand-shaken emulsions.

Most laboratory workers, have, up to the present, worked with hand-shaken and, therefore, relatively coarse-grained emulsion mixtures; these mixtures

have usually shown great tendency to cream and yet, nevertheless, they have been stable for months. Thus the writer has kept hand-shaken emulsion mixtures of toluene, benzene, paraffin oil, *etc.*, in aqueous gelatine or soap, which have fully creamed during a period ranging from a few hours to a few days, for months, without any appearance of disperse phase in mass from the cream. Pickering (2) stood his emulsion mixture twelve weeks to cream, without cracking into phases taking place. So that quick creaming does not necessarily mean low stability of the emulsion mixture. As a matter of fact, from the foregoing arguments, it will be seen that the relatively small interfacial surface and low rate of Brownian movement (zero in an emulsion containing globules greater than $4\ \mu$, as is possible in a coarse-grained emulsion) of hand-shaken emulsions should tend to greater stability. That the adsorbed layer is of greatest effect in inducing stability is shown by the fact that concentrated emulsion creams (containing 74 per cent. of disperse phase), where the globules are touching, are quite stable, and that Pickering's 99 per cent emulsion of oil in water (2) was quite stable, despite the fact that globules of disperse phase must, in such an emulsion, be not merely touching, but actually crushed together.

True stability would be indicated by the time taken for the emulsions to show signs of " breaking " or " cracking " into the component phases. Thus Nugent (16), Pickering (2), Hardy (17), *etc.*, are on the right lines in their assumption of stability, though it must be added that Nugent's case is a special one, the stability of the emulsions being determined in the presence of a foreign substance (sodium hydroxide) which has a dissolving effect on the adsorbed layer of emulsifying agent used (gelatine).

The true stability of emulsions could therefore only be compared by standing emulsions under standard conditions and noting the time of appearance, or of completion of cracking into layers of both phases ; thus we could only compare the stabilities of emulsions with reference to some extra factor, *e.g.*, the stability at a certain temperature, or in the presence of a foreign agent such as sodium hydroxide, *etc.* As standing usually results in creaming of the so-called emulsion, the stability would thus be the stability of the cream or true emulsion under the given conditions.

The stability of *mixtures* of emulsion with excess external phase is probably one of the most important factors governing the use of paraffin oil as an insecticide in spraying on the large scale ; an approximate 1 per cent. emulsion of paraffin oil in soft soap solution would be used ; this would give a cream containing about 74 per cent. by volume of oil, leaving a clear aqueous underlayer. In spraying, therefore, unless *very* efficient mixture by stirring or pumping were resorted to, the tendency would be for part of the foliage to receive large amounts of oil which could cause scorching, as the upper layers of the emulsion mixture would become progressively richer in oil content.

EFFECT OF WIDTH OF CONTAINING VESSEL ON RATE OF CREAMING.

Milk is an emulsion, the cream being the true emulsion which rises to the surface. It is an old belief, held by many farmers, that to obtain cream easily it is necessary to keep the milk in wide shallow pans ; the milk is then said to cream more quickly and more completely.

50 c.c. lots of a 0.4 per cent. solution of commercial Coignet's gold leaf gelatine and 50 c.c. lots of toluene were formed into emulsion mixtures by intermittent hand shaking in a 500 c.c., a 250 c.c. and a 100 c.c. cylinder. The three cylinders were given a final common shaking and were then stood side by side, the lines of demarcation of the creams and the aqueous underlayers (quite definite) being read at definite times ; the volumes of cream present at these times could thus be calculated, and, assuming all the oil to be present in the creams at any time, the average oil content of the creams could be worked out (Table B.) :

It will be seen that after the first four minutes the creams became more concentrated as regards oil in the larger vessels ; thus to reach a volume concentration of oil in the cream of 66.82 per cent., the times required for the 500 c.c., 250 c.c., and 100 c.c. cylinders were 27, 52 and 67 min. respectively.

The ratios of the internal diameters of the cylinders to the lengths of 100 c.c. columns of emulsion mixture in the cylinders were respectively 0.7267, 0.3610 and 0.2410 for the 500 c.c., 250 c.c. and 100 c.c. cylinders. It is thus obvious that the wider the vessel, the quicker and more complete the creaming of a given volume of emulsion mixture ; the old practice of farmers referred to before with regard to the creaming of milk has thus a scientific basis.

The importance of this more rapid creaming in the case of wide vessels will be quickly perceived by the sprayer ; spray fluids are usually made in 40 gallon casks on the farm ; the ratio of the diameters of these casks to their lengths will probably be somewhere near to 0.75. Hence, unless frequent and thorough agitation or pumping is resorted to, a paraffin emulsion mixture will quickly tend to segregate into cream and aqueous underlayer, and scorching of foliage will result.

EFFECT OF DILUTION OF EMULSION MIXTURES ON RATE OF CREAMING.

Five c.c. of toluene and 5 c.c. of a 0.5 per cent. solution of sodium oleate were shaken together in a 100 c.c. cylinder till an emulsion mixture resulted ; the rate of creaming was then noted. The contents of the cylinder were then re-shaken with definite amounts of 0.5 per cent. sodium oleate solution, the rate of creaming being noted in each case. (N.B.—Sodium oleate solution was used as a diluent instead of water because a better line of demarcation resulted between the soap solution underlayer and the supernatant cream, as Pickering also noticed (2)).

TABLE B.

Time after Formation of Emulsion Mixture. (min.)	500 c.c. cylinder.			250 c.c. cylinder.			100 c.c. cylinder.		
	Vol. of Underlayer (c.c.)	Vol. of Cream (c.c.)	Vol. Conc. of Oil in Cream (%).	Vol. of Underlayer (c.c.)	Vol. of Cream (c.c.)	Vol. conc. of Oil in Cream (%).	Vol. of Underlayer (c.c.)	Vol. of Cream (c.c.)	Vol. conc. of Oil in Cream (%).
0	0	100	50	0	100	50	0	100	50
2	0.5	99.5	50.25	1.6	98.4	50.82	1.8	98.2	50.93
4	2	98	51.02	2	98	51.02	2	98	51.02
7	5	95	52.64	4	96	52.08	4.4	95.6	52.30
12	10	90	55.56	6	94	53.20	5.5	94.5	52.91
17	15	85	58.83	9	91	54.95	6.5	93.5	53.48
22	20	80	62.50	12	88	56.82	8.8	91.2	54.83
27	25	75	66.82	15	85	58.83	10.8	89.2	56.06
32	26	74	67.57	16	84	59.53	12	88	56.82
37	28	72	69.45	20	80	62.50	14	86	58.15
52	31	69	72.47	25	75	66.82	20.5	79.5	62.90
67	32.5	67.5	74.08	29	71	70.42	25	75	66.82
72	33	67	74.63	31	69	72.47	28	72	69.45

TABLE C.

Time after Formation of Emulsion Mixture. (min.).	Total Volume of Emulsion Mixture :					
	10 c.c.	15 c.c.	20 c.c.	30 c.c.	50 c.c.	100 c.c.
	Vol. cream.	Vol. cream.	Vol. cream.	Vol. cream.	Vol. cream.	Vol. cream.
0	—	—	—	—	—	—
5	—	12.0	14.5	18.5	5.0*	1.0*
7	—	—	11.75	—	—	—
10	—	10.0	10.0	10.0	9.75±	4.5*
15	9.5	8.75	9.0	9.25	9.0	7.0*
20	9.25	8.25	8.5	—	8.5	7.5±
25	9.0	8.0	8.25	8.75	—	—
35	8.75	7.75	8.0	8.0	8.0	7.5
45	—	—	—	7.9	—	—
50	8.0	7.0	7.25	7.75	7.0	7.5
65	7.75	6.75	7.0	7.5	—	—
80	7.5	—	—	—	—	—
95	7.25	—	—	—	—	—
110	7.0	—	—	—	—	—

* Ordinarily the emulsion mixture shows a definite line of demarcation from the aqueous underlayer, the supernatant cream appearing regular ; in the cases marked with an asterisk (dilute emulsion mixtures), there are " rims " of " concentrated " cream, and the underlayer is a graduated and dilute emulsion mixture of cream and excess aqueous phase. Thus the rim of cream becomes larger in volume before showing the normal behaviour commencing at the stage marked ±.

In all cases in the above table the emulsion mixtures contain 5 c.c. of toluene ; the table shows that the supernatant cream (when the mixture is creaming in a normal manner) always tends to approach the mathematical limit of volume concentration of disperse phase at a roughly approximate rate. This means that emulsion mixtures of all dilutions cream roughly in the same time, i.e., that in the case of dilute emulsion mixtures such as would be used in spraying, the aqueous underlayer, though much greater in relative bulk than with concentrated emulsion mixtures, clears in the same time. Moreover, in the case of dilute emulsions, a rim of concentrated cream is apparent very quickly. These two facts are important to the sprayer ; for unless *very* efficient stirring of the emulsion mixture takes place, the bulk of the mixture will be quickly innocuous to insects, whilst the top layer will have a decided scorching action on foliage. It is doubtful whether any device fitted to the pump would be capable of thoroughly mixing the cream and underlayer from emulsion mixtures.

SOLUTIONS OF PARAFFIN OIL.

From the foregoing experiments, it will be seen that one of the main causes of the failure of emulsion mixtures used in spraying is the rapidity with which the cream rises to the surface, the creaming taking place more rapidly or

completely in wide vessels such as are used as containers in spraying, the fault being accentuated by the (necessary) use of dilute emulsion mixtures.

To make an emulsion mixture cream more slowly, three methods would probably be possible:

(1) To reduce the size of the disperse phase particles by homogenisation, (thus increasing adsorption and viscosity).

(2) To increase the viscosity of the emulsion mixture.

(3) To try to equalise the densities of the disperse and continuous phases.

Method (1) would probably be very costly; method (2) would entail the addition of large quantities of protective colloids such as gelatine and, in order to prevent the creaming of dilute emulsion mixtures, the continuous phase would probably have to possess such a high viscosity as to make the mixture unsprayable; method (3) seemed a novel and promising method, and hence experiments were carried out on this.

To equalise the densities of the disperse and continuous phases, so that rising of the disperse phase particles is retarded, the addition of some third substance is, of course, necessary; a mixture of cresols (pure "cresylic" acid) was chosen.

The mixed cresols have usually a specific gravity of about 1.05, *i.e.*, higher than that of water or of soap solutions (18); moreover cresols are completely miscible with oils such as paraffin, whilst they are soluble to a limited extent only in soap *solution*, the solubility depending on the concentration of soap (*e.g.*, *Lysol* contains some cresol in solution).

On mixing a dilute soap solution, paraffin oil and cresylic acid, and shaking, it is therefore conceivable that the greater part of the cresols would be dissolved in the oil (tending to make the density of the disperse phase particles more nearly approximate to that of the continuous soap solution phase) and thus retard creaming. This should be more especially the case if the cresols are present in any amount greatly in excess of that which could be dissolved by the soap solution at the dilution used.

Experiments were made with soap solution—paraffin oil emulsion mixtures, adding differing quantities of the cresols and re-shaking vigorously. It was found that creaming could be retarded so that it took months to complete; examples will be given in a future paper where dilute emulsion mixtures were made stable (or lasting), creaming being absent after a few days, even in the case of 1 per cent. oil emulsion mixtures. The stability of these emulsion mixtures is obviously an advance on the emulsions now commonly used.

In one case under observation, where the soap solution phase was fairly concentrated, addition of cresols drop by drop was found to cause complete solution of the paraffin; a solution of paraffin, of course, would present undoubted advantages over paraffin emulsion mixtures, the particles of paraffin being

molecular (or colloidal if a colloidal solution) in size and, as no creaming would be possible, being capable of application in a uniform manner to the trees. Moreover, were the paraffin solution without "scorching" action on foliage, a cheap spring spray might be formulated, "sucking" insects being effectively sprayed at the most vulnerable period of their life history.

Preliminary experiments were made with the object of gaining a rough idea of the concentrations of soap, paraffin oil and cresylic acid necessary to give solutions on adding water; the soap used was a green soft soap of unknown origin and quality (probably a "Sapo Mollis" of pharmacy (19)). The best results seemed to be given by about 2 gm. of soap, 1 c.c. of cresols, and 0—3 c.c. of paraffin oil; these amounts were triturated in a mortar, and formed perfectly homogeneous solutions (to the eye). Water was added drop by drop to about $\frac{1}{2}$ c.c. of these solutions. The first drop or two of water dissolved in the mixtures; more water gave mucilaginous jellies, and emulsions, whilst excess of water completely dissolved the mixture, a slight turbidity being developed at extreme dilutions due to precipitation of acid soap. A detailed examination of similar results will be given later; it is only necessary here to discuss the preparation of these solutions of paraffin—cresols—soap.

Two or three easy methods of making these solutions were noted; one could (*a*) grind the soft soap and cresols to a homogeneous solution and add the oil, or grind the soap, cresols and paraffin; (*b*) heat the soap and cresols till solution resulted, and add the oil; (*c*) stand the soap in the cresols for a few days, giving an occasional stirring, until solution resulted, and then add the oil. These methods are much better than making an emulsion mixture of soap solution and paraffin first, and then adding cresols, and shaking till solution results; for by them a concentrated solution of paraffin oil (suitable for transmission by rail) is made, which will dissolve very easily with gentle stirring on pouring into excess of water.

SUMMARY.

It is shown, as Pickering showed, that so-called emulsions tend to cream to give a clear aqueous underlayer and a cream containing approximately the mathematical limit (74 per cent.) of disperse phase; it is argued that this cream is the only true emulsion, and that under ideal conditions it would contain the mathematical limit of disperse phase; mixtures of this cream or emulsion with excess continuous phase are termed emulsion mixtures.

The difference between the stability, and the stability to creaming, of an emulsion mixture is pointed out; in the first case lack of stability should be judged to mean the "cracking" of an emulsion into separate *layers* of disperse and continuous phases; in the second case (which is often confused with true

stability) lack of stability results in *creaming* to the true emulsion ("cracking" into disperse phase in mass usually taking place after formation of this cream).

The creaming effect is probably one of the chief causes of failure of emulsion mixtures in spraying ; the use of wide vessels as containers and the employment of dilute emulsion mixtures accentuate this defect.

Equalisation of densities of the disperse and continuous phases of an emulsion mixture by adding a substance of greater specific gravity than water, completely miscible with the disperse phase and showing limited miscibility with the continuous phase, gives very stable or lasting emulsion mixtures in the case of paraffin oil. In some cases actual solution of relatively large amounts of oil is obtained ; the easiest methods of preparation of these solutions are discussed, and the probable use of the solutions as foliage sprays indicated.

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PLUM APHIS AND BROWN ROT CONTROL.

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Introduction.

In the constant effort to produce crops of greater quantity and high quality the fruit grower is face to face with the urgent necessity of controlling parasites. These parasites may be entomological and mycological and it has been the object of applied research to work out the methods suitable for the control of all the possible pests and diseases. This work has resulted in a larger number of separate control measures adopted in most cases to particular pests and diseases only and these recommendations can be found in textbooks and similar sources of information. It might well be asked, however, whether some of these recommendations with their numerous sprayings for maladies could ever be carried out without the grower becoming bankrupt in the process and the question becomes more acute still when not one but several maladies have to be controlled at the same time.

The writers feel that the view point already taken by some workers that the proper criterion of disease control is the net profit accruing to the grower is the correct one. The problem is, after all, the grower's, and not primarily the plant pathologist's and there is obviously an economic limit to the number of treatments that a grower can apply to a crop plant no matter how many maladies are affecting it. In extreme cases it may be even more profitable to destroy the crop plant rather than to attempt to control disease by repeated costly treatments. With these considerations the writers have approached the question of control of plum maladies and have endeavoured to find out single treatments that would give the highest possible control of the commonest and most important troubles of plum trees in general.

Description of Experiment.

It was originally intended to select an orchard where both Aphis and Brown Rot might reasonably be expected to develop. Fortunately sufficient winter moth caterpillar appeared to give data as regards control of this pest also.

Thus the orchard proved to contain the three chief troubles of the plum. The writers are of course well aware that other troubles do occur but they contend that such are not of sufficient frequency to warrant inclusion in a regular spray programme.

The orchard selected for the trial was situated in Gloucestershire and occupied about seven acres. About one third was interplanted with black currants. The trees were tall half standards of the varieties Victoria and Purple Pershore and apart from the disease present were well grown specimens. They had suffered severely from Brown Rot during the previous year and events proved that both aphis and winter moth eggs were present in sufficient numbers to give data on these two pests also.

PLAN DIAGRAM.

	Treatment.	Date of Application.	Number of Trees.			
I	Carbo fluid 7 per cent.	31.1.24	1–12	95–106	191–202	287-298
II	L.S.+Ca. Caseinate 1 : 15+.2 per cent.	7.3.24	13–24	107–118	203–214	299-310
III	L.S.+Ca. Caseinate 1 : 30+.2 per cent.	7.3.24	25–36	119–130	215–226	311-322
IV	Caustic Soda + Liquid Soap 10 lbs. 3 galls. Water 100 galls.	3.4.24	37–48	131–142 167–176	227–238	323-334 Not sprayed Used as Control.
V	Caustic Soda+Liq. Soap+ Paraffin 10 lbs. 3 galls. Water 100 galls.	4.4.24	49–60	143–154	239–250	335-346 Not sprayed. Used as Control.
VI	Caustic Soda+Liq. Soap+ Nicotine 10 lbs. 3 galls. + 8 ozs Water 100 galls.	5.4.24	61–72	155–166	251–262	347-358 Not sprayed. Used as Control.
VII	Control (Untreated)		73–84	167–178 (see above)	263–274	359-370
VIII	Carbo fluid, 4 per cent.	31.1.24	85–94	179–190	275–286	371-378

The plan diagram shows the lay out of the experiment as decided upon in the first instance and the slight modifications which had to be made owing to the danger of injury to an intercrop of black currants in one half of the plantation. The question of intercrops is again referred to below.

RESULTS.

The following Table shows the results of the spraying in regard to their effectiveness against Aphis, Brown Rot, and Caterpillar damage.

	Treatment.	Aphis Control.	Brown Rot Control.	Caterpillar Control.
I	7 % Carbo	Complete.	Complete.	Fairly good.
II	L.S. 1 : 15	Very slight.	Slight.	Very slight.
III	L.S. 1 : 30	Do.	Very slight.	Do.
IV	Caustic + Soap	Complete.	Slight.	Complete.
V	Do. + Paraffin	Complete.	Do.	Do.
VI	Do. + Nicotine.	Complete.	Do.	Do.
VII	Control (No treatment).	Medium—bad attack.	Medium—bad attack.	Medium attack.
VIII	4 % Carbo.	Complete.	Fairly good.	Fairly good.

It will be seen that none of the spraying materials used completely controlled Aphis, Brown Rot, and Caterpillar. The results which were recorded on May 24th, 1924, can be summarised as follows :—

Lime Sulphur Washes.

Of the two strengths used, the stronger was slightly the better being a little more effective against Brown Rot. Lime Sulphur partially controlled all three maladies but it was felt that the benefit derived was not sufficient to justify recommending its use against all or any of the troubles concerned.

Caustic Washes.

The results were the same for all three and as far as could be observed nothing was gained by adding either Nicotine or Paraffin to the Caustic Soda and Soft Soap solution. All three were highly satisfactory against Aphis and Caterpillar but their action on Brown Rot disease was only slight. The effectiveness of these washes against Aphis and Caterpillar might be due to the fact that they were applied later in the season than the other sprays and killed newly hatched insects.

Carbo Fluids.

The higher strength (7 per cent.) completely controlled Aphis and Brown Rot and was also fairly effective against Caterpillar. The lower strength (4 per cent.) gave somewhat similar results except that it was not quite so satisfactory against the Brown Rot. This might be due to the fact that the trees sprayed were very seriously attacked by Brown Rot in the previous year and it required the stronger concentration under such conditions. The only sign of Brown Rot on trees sprayed with 7 per cent. Carbo fluid were a few pustules which had developed subsequent to spraying on dead twigs killed by the previous year's attack.

Discussion.

The wood killed in the previous year had not been removed and there was a very considerable amount of it on all the trees. The trees were of the standard

type and were from twelve to sixteen years old. It has been recommended to cut out all dead branches and twigs as a supplementary measure against Brown Rot. This operation is extremely sound and should always be done in gardens or small plantations. It is felt, however, that it is impracticable in large commercial plantations of fully grown standard trees owing to the difficulty of recognising from the ground the smaller dead twigs and the cost of labour of such an operation, if done when the trees are in a dormant stage.

It is felt that the most satisfactory method of dealing with these three troubles would be to spray first with 7 per cent. carbo fluid as well as apply grease bands to the tree trunks. These two operations will satisfactorily control all three. Later in the spring when the trees are in leaf the larger dead branches can be more easily recognised and can be removed more effectively, more quickly and consequently with much less cost in labour to the grower. In subsequent years the application of 4 per cent. strength of Carbo Fluid and grease bands would effectively control all three when used on trees which were moderately clean to start with. The use of the weaker strength would almost halve the cost of the spraying fluid which in large plantations would be very considerable. This treatment though applicable to standard orchards in general admit of certain exceptions in special cases. Thus in the case of young orchards for the first few years after planting, grease banding is relatively laborious and arsenate spraying relatively easy. Arsenate will tend to control Tortrix moth which, in a young orchard where straight growth is essential, terminal growth is not so necessary, the framework being formed already, grease banding may be done instead of arsenate spraying. Spraying could be further reduced though at the same risk by omitting non-susceptible trees from the yearly programme.

There is a further advantage in using the Carbo Fluid which is applied when the tree is still dormant and when such intercrops as Black Currants, Gooseberries, Red Currants, etc., are also dormant. In this case there is no danger of any damage to these intercrops. The caustic washes are applied later just when the plum buds are about to open at which time there is danger of damage to the intercrops which are then in leaf.

Having come to the conclusion that the Carbo Fluid was the most satisfactory remedy, it is intended this year to test out different brands of Carbo Fluids at different strengths with a view not only to find out which is the best product on the market but also to strike as nearly as possible the economic balance of cost and efficacy by reducing the strength as far as possible.

In conclusion we wish to express our indebtedness to Mr. A. McKibbin, of Kents Green, Taynton, Glos., for putting his orchard at our disposal for the trial, and for extending to us his whole-hearted co-operation and hospitality.

BLACK CURRANT VARIETY TRIALS:

Reliability of Results.

THE VARIABILITY IN CROPPING OF INDIVIDUAL BLACK CURRANT BUSHES AS A GUIDE TO THE SUITABLE SIZE OF EXPERIMENTAL PLOTS.

By R. G. HATTON, N. H. GRUBB and R. C. KNIGHT.

Planning Field Trials: General Considerations.

When we planned our first series of black currant variety and manurial trials, although we realised that our material was certain to show some variation, we had no idea how great a variation to expect, since individual bush records had seldom, if ever, been kept by earlier workers. Hence we had no basis for calculating the optimum size for our experimental plots.

The problem of the optimum size of plots arises from the variability of individual bushes of the same variety. This variability persists in almost all biological experiments, even under the most carefully controlled conditions. It will be obvious that, under field conditions, its elimination will be still more difficult. We are therefore in search of the minimum number of individuals which will give an average, or "mean," crop weight figure truly representing the characteristics of the variety, and not seriously distorted by chance extremes.

At the outset of our black currant experiments we used the customary method of group records from each plot, and, although the plots in any one of our experiments were of uniform size, they have varied in different experiments from units of 8 bushes to 112. We had no means of telling which of these extremes was likely to be nearer to the minimum required for reliability.

Questionable Value of Group Records.

Close observations soon forced upon us the conclusion that such group records were of questionable value. For instance, in our original manurial trials with black currants, about the fifth or sixth year the whole method became complicated by the appearance of varying attacks of both big bud and "reversion." Since both these troubles are known to affect the cropping of the bushes, we felt obliged to draw a line somewhere, and leave out of our group records the worst affected bushes. We thus came face to face with a very

serious cause of individual variability, and soon found ourselves forced to record the bushes individually.

Even apart from this question of disease, it was obvious that quite local conditions, of soil, site or cultivation, materially affected the uniformity of the results. For instance, we soon observed that proximity to a hedge or poplar wind-break adversely affected the growth and cropping of the bushes. Again, as in the case of top fruit plantations, headland bushes were frequently noticed to be the best.

Individual Bush Records.

Therefore, in 1920, we laid down new manurial and variety trials, upon which it was decided to keep individual bush records of cropping and the incidence of disease. These records have now been accumulated for four years, and enable us to draw tentative conclusions as to the actual variability to be expected, and therefore the best sizes for experimental plots.

For our present purpose the second series of variety trials mentioned above will be here discussed.

The plots consisted of 73 bushes of each of the five chief varieties, propagated from bushes which for some years had been under close observation at East Malling. The records here analysed are based on from 60 to 70 bushes of each variety, the remainder having had to be discarded owing partly to "reversion," and partly to the need for reserving a few bushes for other experimental purposes.

Control of Field Conditions.

The bushes under review were planted on ground that had been cropped and manured uniformly for seven years; the site itself was chosen for the apparent evenness of the soil. The bushes were all yearlings when planted, and were all cut to near ground level at the same time, soon after planting. In all respects the subsequent treatment has been as uniform as possible; the pruning (to which we shall have cause to refer again below, as an element in the variability) has always been on the light side, and has been done throughout by members of the Staff who realised the importance of uniform treatment. The whole object in view was to secure as accurate comparative crop weights as possible, since the whole plantation constituted our main variety trial. It should, perhaps, be stated that, owing to limited space, these bushes had to be interplanted between young apple trees, of very variable size, at 15 feet apart. This may have added somewhat to the variability of the bushes. Each of the five varieties under comparison was in an unduplicated row, 15 feet from its neighbour, and 360 feet in length.

Records Here Presented.

The first crop was picked in 1921, but the amount was then naturally so small that the records for that year are not particularly stressed in the statistical analysis; they are, however, presented in order to show certain interesting points in the early cropping of the varieties.

It does not appear to us necessary to present here the twenty complete sets (five varieties each for four years) of individual bush records, since, as subsequent tables will show, the " probable errors " for the different varieties and seasons are not strikingly different. But for purposes of our own references in this paper, and in the hope that some statistician may be tempted to analyse these figures on his own account, we present as an appendix the complete data for the variety French, and in graph form similar data for Baldwin. These two have consistently differed more widely in cropping than any other pair of varieties.

Necessity for Critical Examination of Records.

These individual bush records of Baldwin and French themselves afford an excellent example of the variability we are studying. Even if, taking either variety by itself, we work out the average crop weights for each adjacent group of six bushes of that variety, we still find, from group to group, differences as wide as frequently occur between distinct varieties. The fact that there exists such wide variation within a single variety often results in the overlapping of group averages of varieties actually very different. Examine, for instance, the average crop weights for adjacent groups of 6 bushes of the varieties French (Merveille de la Gironde) and Baldwin. (See Table I.)

Table I.

Average Crop Weights for Adjacent Groups of 6 Bushes.

	Year 1923.		Year 1924.	
	French.	Baldwin.	French.	Baldwin.
Group.	oz.	oz.	oz.	oz.
1	22.0	69.3	82.8	104.8
2	28.5	51.7	103.3	104.0
3	20.2	68.8	91.0	114.5
4	23.5	52.8	83.0	92.3
5	19.8	49.3	88.3	87.5
6	23.0	58.7	85.5	94.2
7	19.5	65.0	94.5	104.7
8	20.5	48.5	88.0	93.0
9	15.8	50.0	86.0	106.2
10	15.0	58.8	82.0	108.5
11	18.0	64.2	—	102.0
12	—	50.3	—	—

From this Table it will be seen that, whilst in 1923 even the extremes of the two varieties came nowhere near overlapping, in 1924, five French groups (Nos. 2, 3, 5, 7 and 8) were all higher than the lowest group of Baldwin (No. 5), and five groups of Baldwin (Nos. 4, 5, 6, 8 and 11) were lower than the highest group of French (No. 2). This happened in spite of the fact that the averages for the whole plots were widely enough separated in 1924 (as judged by the " probable error ") to show a difference in favour of Baldwin extremely likely to be repeated in further trials. Since this can occur with strictly controlled material and varieties as widely different as any in our trial, we feel that we can no longer rely on the comparative results obtained from small plots.

METHOD OF EXAMINATION—THE PROBABLE ERROR.

We must then adopt a size of plot sufficient to smooth out this variability, and to show how this may be done we propose to use the mathematical conception called the " probable error."

In order to explain what we mean by the " probable error " we propose to use some of our actual figures as examples ; therefore Table 2, presenting the average crop weights per bush of five varieties for four years, with the " probable errors," is introduced at this point.

The " probable error " shows within what limits there is an even chance of the true cropping power lying, i.e., it gives a measure of the limits within which the results from similar trials are likely to vary. For example, it will be seen in Table 2 that the variety Seabrooks cropped in 1922, 14.1 ozs. per bush ; the figure $\pm .27$ which follows is the probable error, and shows that there is an even chance of the true cropping power lying between $14.1 - .27$ and $14.1 + .27$, i.e., between 13.83 and 14.37. In other words, if the experiment were repeated 100 times under similar conditions, the crop figure would lie between these limits (13.83 and 14.37) fifty times, and outside them fifty times. The size of this probable error, as will be shown later, is ruled very largely by the number of individuals in the plot.

WHAT DIFFERENCES ARE SIGNIFICANT ?

What we are aiming at is to be sure that the differences shown by our experimental results are significant, i.e., that a repetition of the experiment under similar conditions would be likely to give a similar result. For instance, to take a further example from Table 2, if the average crop weights of Goliath and Boskoop in 1922 are compared without reference to the probable error, it would appear that in that year Goliath bore a somewhat heavier crop, which, when worked out on an acreage basis, represents a difference of 42½ lbs. per acre, on a total crop of about 1,200 lbs. (bushes only two years old). However, when the probable errors are taken into account, it will be seen that there is a

TABLE II.

Average Weight of Crop per Bush (ounces). With Probable Errors.

	No. of Bushes.	1921.	No. of Bushes.	1922.	No. of Bushes.	1923.	No. of Bushes.	1924.	No. of Bushes.	1922, 1923, and 1924 together, calculated independently.
French ..	70	2.85 ± .36	67	16.1 ± .32	66	20.5 ± .54	61	88.2 ± 1.21	61	124.6 ± 1.66
Seabrooks ..	70	3.92 ± .46	70	14.1 ± .27	67	25.7 ± .50	62	91.1 ± 1.17	62	130.8 ± 1.43
Boskoop ..	70	1.26 ± .21	70	15.9 ± .35	68	23.6 ± .38	67	108.1 ± 1.60	67	147.4 ± 1.92
Goliath ..	70	1.07 ± .27	70	16.5 ± .41	70	35.0 ± .89	66	96.6 ± 1.69	66	147.5 ± 2.46
Baldwin ..	71	6.0 ± .57	73	29.9 ± .65	73	57.1 ± 1.28	70	99.6 ± 1.68	70	186.2 ± 2.56

considerable chance that the respective ranges within which the true cropping powers lie may overlap, and that in 1922 the apparent differences in cropping may have been due to chance. Thus it is impossible from these figures to decide which variety possesses the greater cropping power, owing to the difference between them not being truly significant. On the other hand, if we refer again to Table II, we can see at once how significant is the superior cropping in 1922 and 1923 of Baldwin over any other variety.

RELATIONSHIP BETWEEN EXPERIMENTAL DIFFERENCE AND PROBABLE ERROR.

Where the experimental difference (i.e., the difference between two averages) is many times larger than the probable errors (as in the example just quoted, of Baldwin's crop in 1922 and 1923 compared with that of any other variety), it is obvious without further calculation that the result is significant, the chances of overlapping being in such a case very small. But where the experimental difference and the probable errors are not so widely separated, it is necessary to decide upon some criterion by which to judge the significance of the result; or, in other words, to decide how many times the experimental difference must be larger than the probable error before we can regard the result with confidence. Fortunately for non-mathematicians like ourselves, calculations have been made which give us, for any particular relationship between the experimental difference and the probable error, the number of chances there would be in favour of our obtaining a similar result on repetition of the experiment, or, in other words, how frequently we could expect to get a result in the same direction.

Therefore, we have to ask ourselves what number of chances is good enough; and in answering this question we must remind ourselves that experimenters should not take undue risks. One of the calculations referred to above shows that, if the experimental difference is 3.2 times its probable error, there are thirty chances to one that the result is significant, or stated otherwise, that thirty-one repetitions of the experiment under similar conditions could be expected on the average to give a result in the same direction thirty times, and a contrary result once.

For instance, if we compare the average crop weights of Seabrook's and Boskoop in 1923, we find that the difference between these averages (i.e., the experimental difference, 2.1 oz.) is slightly over 3.3 times its own probable error (obtained by squaring the probable error of each average, adding the squares together, and taking the square root). If we repeated this experiment under similar conditions, with the same number of bushes, a large number of times, we could expect that, on the average, Seabrook's would crop better than Boskoop, as in this experiment, thirty out of each thirty-one times.

For the experiments under discussion here we consider that such a thirty to one chance should surely be good enough to indicate a real difference in the

direction shown, and we propose to use this severe test henceforth as the criterion of the significance of our results. That is to say, when the experimental difference is 3.2 times (or more) its probable error, we feel satisfied that this difference is a real difference of cropping power, and is not due to chance variation.

It seems to us probable that, if a single season's result can give us thirty chances to one in favour of its significance, the repetition of a similar result for several successive seasons can be regarded with still greater confidence, even though the same bushes are used throughout. Such repetitions are seen to occur frequently in Table II.

Examination of Records in Light of this Criterion.

Before proceeding to indicate the minimum size of plot demanded by this criterion, we propose to show what the value of our results would have been had we had various numbers of bushes from six to seventy.

An examination of the crop figures for Baldwin and French, given in the Graphs and Appendix, shows that in one year out of four (1923), single bush plots could almost have been relied on to give a significant result, though four out of seventy-three bushes of Baldwin actually gave a smaller crop than the best bush of French, and thirty-five out of sixty-six bushes of French yielded more than the poorest cropping bush of Baldwin.

We have already shown in Table I how the results with six bush Groups of French and Baldwin overlap in 1924 (though not in 1923) and we propose to seek an answer to our question by following up these lines of thought. Table III reproduces the 1923 portion of Table I with the probable errors included.

Table III.

Crop, in oz., of adjacent groups of 6 bushes in 1923 with Probable Errors.

Group.	French.	Baldwin.
1	22.0±1.35	69.3±8.70
2	28.5±1.76	51.7±4.37
3	20.2±1.17	68.8±2.94
4	23.5±1.65	52.8±2.00
5	19.8± .61	49.3±3.25
6	23.0±1.41	58.7±3.26
7	19.5±1.57	65.0±1.78
8	20.5±1.22	48.5±5.55
9	15.8±1.49	50.0±2.13
10	15.0±1.56	58.8±4.90
11	18.0±1.28	64.2±4.13
12	—	50.3±3.35

It will be readily seen that in 1923 there was a very small chance of any six bushes of Baldwin cropping as low as any six bushes of French. Thus the two seasons gave a totally different result with six bush units. It is of interest

therefore to see how many bushes would have been required in 1924 to give a truly significant result.

If the same bushes are taken in adjacent groups the crop figures for 1924 are as shown in the following tables of progressively larger groups.

Table IV.

1924 *Crop in ozs. of French and Baldwin in adjacent groups of* 6 *bushes with Probable Errors.*

Group.	French.	Baldwin.
1	82.8±4.95	104.8±7.12
2	103.3±3.59	104.0±6.98
3	91.0±2.31	114.5±4.26
4	83.0±3.23	92.3±2.81
5	88.3±2.66	87.5±7.27
6	85.5±3.29	94.2±9.78
7	94.5±2.73	104.7±2.88
8	88.0±5.28	93.0±4.13
9	86.0±3.66	106.2±4.31
10	82.0±4.33	108.5±3.81

Taking each parallel pair of groups we find that on the average the experimental difference is only 2.2 times its probable error, giving about seven chances to one in favour of a similar result on repetition.

If we had had only six bush plots and if in our selection of these six bushes we had been exceptionally fortunate, we might have happened to take pairs three, nine and ten and have obtained a result giving from 70 to 900 chances to one in favour of its significance, but in the remaining seven selections the chances in either direction would have been very slight.

Let us see from the following table what happens if we double the size of our groups.

Table V.

1924 *Crop in ozs. of French and Baldwin in adjacent groups of* 12 *bushes.*

Group.	French.	Baldwin.
1	93.0±3.56	104.4±4.75
2	87.0±2.06	103.4±3.30
3	86.9±2.05	90.8±5.86
4	91.2±2.90	98.8±2.67
5	84.3±2.72	107.3±2.76

Again taking each parallel pair of groups we find that on the average the experimental difference is 2.88 times its probable error and therefore the chances are rather higher—namely nineteen to one—in favour of obtaining a similar result on repetition. Here again in only two out of the five cases a fortunate choice of groups would have given us a more or less significant result.

Let us twice more double the size of our groups.

TABLE VI.

1924 *Crop in ozs. of French and Baldwin in adjacent groups of* 24 *and* 48 *bushes.*

24 Bushes.

Group.	French.	Baldwin.
1	90.0±2.05	103.9±2.83
2	89.1±1.76	94.8±3.20

48* Bushes.

Group.	French.	Baldwin.
1	89.5±1.35	99.4±2.15
2	86.9±1.24	96.1±1.96

On the average, in the case of the 24 bush groups, the experimental difference is 2.77 times its probable error, giving sixteen chances to one in favour of its significance. In the case of the 48 bush groups the experimental difference is 3.93 times its probable error. Here the chances are about 120 to one in favour. We have then, with forty-eight bushes, exceeded a size of plot which even in 1924 would have given us a significant result judged by our severe criterion. With the whole number of bushes in our comparative plots—sixty-six French and seventy Baldwin—the experimental difference was 5.51 times its probable error, giving an emphatically significant result with several thousand chances to one in its favour. Even in 1924 then, these plots were distinctly larger than was necessary. The fact that the result was in the same direction and even more significant in the two previous seasons must presumably greatly increase the chances in favour of repetition in a similar direction.

Regarding the figures from another point of view, we find that comparisons of parallel series of the six-bush groups give three significant differences from ten comparisons (i.e., 30 per cent.). The twelve-bush groups give two significant differences from five comparisons (40 per cent.). The twenty-four bush groups give one significant difference from two comparisons (50 per cent.), and the forty-eight bush groups both give significant differences (100 per cent.). This shows the expected increase in the number of significant results as larger groups are taken. We feel satisfied that if our complete records for the five varieties were subjected to a similar analysis, they would strengthen this line of argument.

Before leaving these figures we would like to point out that they afford an admirable illustration of the well-known fact that the size of the probable error is governed by the number of individuals. Take for instance the probable errors for the various sized groups of Baldwin expressed as percentages. The average for the six-bush groups is 5.62 per cent., for the twelve-bush groups

* In order to obtain more than 1 group of 48 bushes from our total row of 73 or less, the 48 adjacent healthy ones at each end of the same row have been taken for this calculation.

3.89 per cent., for the twenty-four bush groups 3.04 per cent., for the forty-eight-bush groups 2.10 per cent., and for the whole seventy bushes 1.69 per cent.

Having now shown the position in regard to the two most widely separated varieties, we can return to the figures set forth in Table II to see what proportion of our experimental results will stand the test we have decided to adopt, viz., a chance of at least thirty to one in favour (which requires, as will be remembered, that the experimental difference shall be not less than 3.2 times its probable error). Table VII below gives, for each of the possible comparisons that can be made in Table II, this relation between the experimental differences and their probable errors.

TABLE VII.

Showing Ratio between the Experimental Differences and their Probable Errors set forth in Table II.

		Seabrooks.	Boskoop.	Goliath.	Baldwin.
French ..	1921	↑1.83	**←3.81**	**←3.95**	**↑4.67**
	1922	**←4.78**	←0.42	↑0.77	**↑19.06**
	1923	**↑7.06**	**↑4.69**	**↑13.93**	**↑26.35**
	1924	↑1.72	**↑9.92**	**↑4.04**	**↑5.51**
	Average for 1922-23-24.	↑2.83	**↑8.98**	**↑7.70**	**↑20.19**
Seabrooks ..	1921	—	**←5.26**	**←5.35**	↑2.84
	1922	—	**↑4.07**	**↑4.89**	**↑22.44**
	1923	—	**←3.34**	**↑9.06**	**↑22.85**
	1924	—	**↑8.58**	↑2.67	**↑4.15**
	Average for 1922-23-24.	—	**↑6.93**	**↑5.85**	**↑18.89**
Boskoop ..	1921	—	—	←0.55	**↑7.80**
	1922	—	—	↑1.11	**↑18.97**
	1923	—	—	**↑11.78**	**↑25.09**
	1924	—	—	**←4.97**	**←3.68**
	Average for 1922-23-24.	—	—	↑0.032	**↑12.13**
Goliath ..	1921	—	—	—	**↑7.81**
	1922	—	—	—	**↑17.45**
	1923	—	—	—	**↑14.11**
	1924	—	—	—	↑1.26
	Average for 1922-23-24.	—	—	—	**↑10.88**

↑ The arrow against each figure in the above Table points to the name of the variety (of the two compared) which cropped the heavier.

It will be seen that where the figures are shown in block type the comparison in question will stand the particular test which we are applying; the other figures will not. If we include the whole four years, and disregard for the moment

the average figure of 1922, 1923 and 1924 together, we find out of forty possible comparisons, thirty-one significant differences. Even if the first year of cropping (1921) be disregarded, twenty-four out of thirty comparisons stand our test.

Now, if we examine the average figures for 1922, 1923 and 1924 together,* we find that the proportion of significant results is higher, and that the chances in favour of the results are often greater than for individual years. This seems to fortify the point we made earlier in this paper as to the enhanced value of results accumulated over a series of years. But we are by no means confident that this is so, in view of the fact that these significant results over the three year period were obtained with the identical bushes throughout, and do not strictly constitute the average of three distinct experiments.

Even now we have not disposed of the question of the response of varieties to different seasonal conditions, as will be readily seen from Table VII. In several comparisons, contradictory results were obtained in different seasons. For example, take the comparisons of Boskoop with Goliath. In 1921 and 1922 we have insignificant results; and in 1923 and 1924 significant results but in opposite directions. Clearly the varieties responded differently to the different conditions obtaining in the seasons concerned. On the other hand, we are faced with a different problem in the comparison of Boskoop with Baldwin. For three successive years the difference in favour of Baldwin was very large and unquestionably significant; moreover similar large differences were shown for four years in the group records from our earlier series of trials. Yet, in spite of this cumulative evidence, the exceptional season of 1924 gave a significant result *in favour of Boskoop.*

These facts surely show that the experimenter must be extremely cautious in generalising from one or two seasons' results. From a strictly practical point of view, the obvious course is to consider the total crops over a series of years. Although we have shown the figures for the years 1922, 1923 and 1924, we are by no means prepared to indicate the minimum period from which it is justifiable to draw conclusions.

Final Deductions as to Sizes of Plots.

Before entering upon a discussion of the practical aspect of our variety trial results, we prefer to carry our theoretical considerations to their logical conclusion. It is apparent from Table VII that, in view of the widely divergent results of the comparisons, it would be at least unwise to dogmatise as to the exact minimum size of plot required in all cases. The proportion of significant

* These average figures, and those in Table II, are not obtained simply by adding the yearly totals together and averaging them, but by taking *the three year total crop of each individual bush* and working out the probable errors and ratios therefrom.

differences, and the degree of their significance, which appear when any of the other varieties are compared with Baldwin, suggest that for these comparisons our plots were extravagantly large. On the other hand, it is obvious that several of the comparisons of the other four varieties amongst themselves would have required even larger plots than those we used to detect a significant difference.

We have said that we will not regard any difference between group averages as significant unless that difference is at least 3.2 times its probable error, so that in planning such trials we must aim at attaining this standard. Now we obviously cannot control the crop differences which we are seeking to determine, but we can control to some extent the probable error, as we have previously indicated, by varying the number of bushes in our plot. It must therefore be our aim to use such a number of bushes as to reduce the probable error of our difference to a value equal to $\frac{1}{3.2}$ $(\frac{5}{16})$ of that difference.

At least two factors must be taken into consideration in coming to a decision as to the size for experimental plots.

(*a*) *The variability of the material to be used, and the amount of control over conditions that can be exercised by the grower or experimenter.*

It may be asked, does the probable error vary much from variety to variety and from season to season? That there may be some slight difference between varieties is shown in Tables IV, V, and VI, comparing French and Baldwin. It is therefore necessary to present complete figures in order to see how far these differences extend. This is shown, in this particular case, by expressing the probable errors (from Table II) as percentages of the means (see Table 8).

TABLE VIII.

Probable Errors (*from Table* II) *expressed as percentages of the means.*

	1921.	1922.	1923.	1924.	1922-23-24 together.
French ..	12.6	1.98	2.63	1.37	1.33
Seabrooks ..	11.7	1.94	1.93	1.28	1.09
Boskoop ..	16.6	2.20	1.62	1.48	1.30
Goliath ..	25.4	2.46	2.54	1.75	1.67
Baldwin ..	9.5	2.18	2.25	1.69	1.37

That this difference between varieties is not after all so striking at once becomes apparent, though curiously, both our "whitish-budded" varieties—Goliath and Baldwin—show, in general, slightly higher probable errors than the "reddish-budded" varieties—French, Seabrooks and Boskoop.

But looking at the three years records of the most distinct varieties of black currant we know, we find that the actual probable error varies between 2.6 per cent. and 1.2 per cent. These three years comprise three very different

seasons, and the figures therefore indicate that climatic conditions do not profoundly affect the probable error. The variation is slight enough to lead us to expect that unknown black currant material (of true race) would show a not dissimilar probable error, provided the conditions were comparable. It seems therefore fair to say that we may in general look for a probable error round about 2 per cent., that is, with sixty to seventy bushes. We propose then to adopt this 2 per cent. as a generally applicable figure.

It should be noticed that there is often a distinct reduction in the size of the probable error as the bushes get older and come into full cropping. We are confident, however, that this is only likely to occur with bushes remaining healthy.

The importance of the control of conditions in other directions also will be obvious. Our results with pruned and unpruned bushes, which will be dealt with later (see page 214) show how serious even this consideration may be.

(*b*) *The probable amount of divergence between the groups to be compared.*

We are not suggesting that the experimenter must have prevision of his results ! But in initiating his trials he will almost certainly have some knowledge of the probable behaviour of his material as, for instance, whether he is likely to obtain small or large differences. Is he trying to detect differences in obviously closely allied varieties like French and Seabrooks, or is he about to compare those of very distinct characteristics ? At any rate, he must decide upon the extent of difference which it is worth while to show. This must, of course, to some extent be a matter of individual judgment. As far as the experimenter is concerned we have suggested that he should adopt a severe test, i.e., that the difference he should look for should be 3.2 times its probable error. Where the probable error of an average crop figure is round about 2 per cent. (as in our experiments), the probable error of a difference between two such averages will be nearly 3 per cent., and this indicates that the experimental difference, in order to be significant, must be about 10 per cent. The grower will approach the question from a different point of view ; what difference will make it worth his while to try a new variety or change his accustomed routine ? Will the 10 per cent of the experimenter satisfy him ? On an average crop of one ton per acre, this would give him an additional 2 cwt. per acre, which at 1924 prices would represent a gross increase of about £6 per acre. Where great additional expense is not involved, as in the selection of the most suitable variety, surely this would be worth while. At any rate for the sake of argument let us accept this difference as of sufficient extent. If we may assume that the probable error of the average of seventy bushes is 2 per cent. and that chances of thirty to one are good enough, then Table IX will show the number of bushes necessary to detect differences of given magnitude.

TABLE IX.

Number of Bushes required to ensure significance of given percentage differences (assuming 2 per cent. p.e. on 70 bushes and chances of thirty to one for significance).

Experimental Differences to be demonstrated. Per cent.	No. of Bushes required.
1	5,680
2	1,428
3	633
5	228
10	57
15	26
20	15
25	10
30	7
35	5
40	4
50	3
60	2
75	1

(Similar tables could be worked out on the basis of larger or smaller probable errors, and higher or lower chances in favour of the result.)*

This table can be used in two ways—given the assumed conditions it shows first how large a plot we must have to detect a given difference, for example to render significant the difference between Boskoop and Goliath in 1922 we should have required about 500 bushes of each ! Second, it shows what difference we can regard as significant if we have a fixed number of bushes. For instance, in dealing with twenty-five bush plots, which are commonly being used for variety trials, it is inadvisable to regard as significant any cropping difference less than 15 per cent.

That this table ought to be of some real value to experimenters with Black Currants we feel confident. At the same time we must point out that the 2 per cent. p.e. assumed as a basis is almost certainly lower than it would be under ordinary field conditions. On the other hand the odds of thirty to one are deliberately chosen on the high side, and it would perhaps be fair to balance a somewhat higher probable error against somewhat lower odds, and so claim for our Table a fairly wide application.

Taking into consideration the three lines of evidence afforded by our own bushes, it does seem possible under approximately similar conditions to suggest a fairly definite and satisfactory number of bushes for general purposes.

We have first the fact that our full plots of from sixty to seventy bushes have frequently given us a margin beyond the safety line ; then it was shown

* For details of this method of treatment see the Journal of the Board of Agriculture, Supplement No.7, November, 1911, "The interpretation of the results of Agricultural Experiments." H.M. Stationery Office.

that, even in the most exceptional year 1924, as we approached groups of fifty bushes we also approached significance ; and now we have Table 9 definitely indicating about fifty-seven bushes as the number required under our conditions to show a significant difference of 10 per cent.

Now we have always emphasised the fact that many of these field trials, such for instance as manurial tests conducted on our land, can at most give general indications and elementary principles, and that each grower must try these out under his own conditions.

We feel that for these general purposes, under ordinary field conditions, we cannot recommend a unit of less than fifty bushes. In coming to such a conclusion we have to face the fact that some of our own trials with smaller numbers of bushes will be of assured value only when they have been repeated. In the absence of the data which we here present, we ourselves made the now obvious mistake, in designing our variety and strain trials, of using large units of bushes for most distinct varieties, and small units for our " sub-types " ! (In the case of our sub-types of Baldwin this mistake has already been remedied with plots of ninety-seven bushes.)

Subsidiary Factors in Bush Variability.

We now come to an interesting point with regard to the effect of pruning on the variability of the bushes. We happen to have two rows of a single variety from the same source, grown under similar conditions, with the exception that, while one is entirely unpruned, the other received normal commercial pruning. The crop figures for three years are shown in Table 10.

Table X.

Cropping in ozs. per bush of Baldwin, pruned and unpruned.

	Pruned.	Unpruned.
1922.	$4.5 \pm .37 = 8.26\%$	$5.9 \pm .32 = 5.41\%$
1923.	$19.9 \pm 1.18 = 5.94\%$	$44.7 \pm 1.67 = 3.73\%$
1924.	$81.2 \pm 3.57 = 4.39\%$	$92.7 \pm 2.34 = 2.52\%$

Though more than one operator had a share in the pruning of these bushes, it was done under the instruction of one individual, and with the avowed object of taking a similar proportion of wood from each bush. Our purpose here is merely to show that the pruning has considerably increased the probable error. We do not propose to deal in this paper with the reduction of crop from its economic aspect.

We have made some attempt to follow out the behaviour of the individual bushes from year to year, with a view to discovering any tendency towards persistent high or persistent low cropping. Graphs have been prepared of the cropping of four varieties over three years ; amongst all these 280 bushes, less than 8 per cent. have shown any tendency towards persistent high cropping,

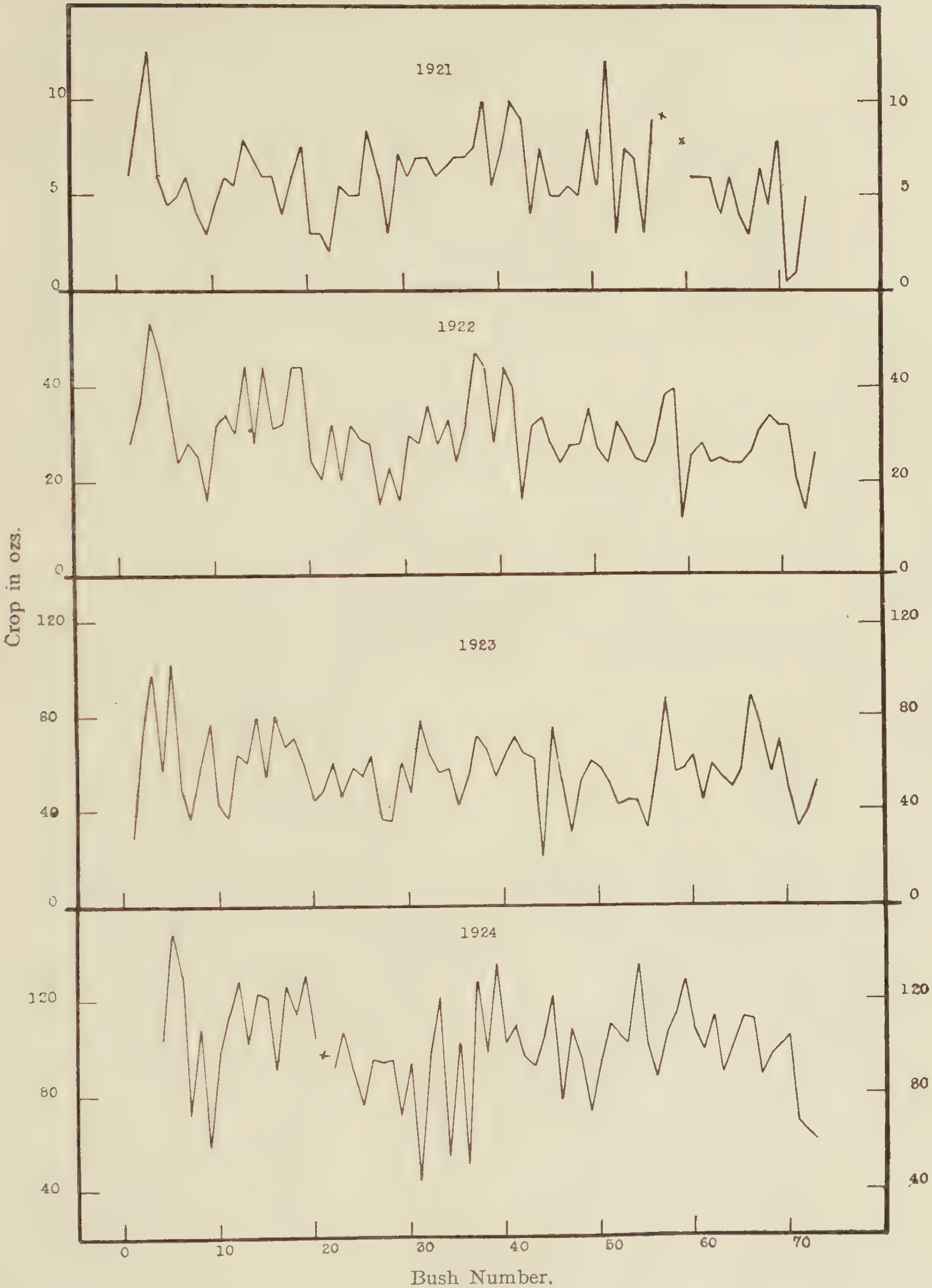

FIG. VII.
Diagram showing cropping on individual bushes of Baldwin.

and about 8 per cent. have shown a similar tendency towards low cropping. The great majority of those bushes that have varied considerably from the average have shown an upward tendency in one year and a downward tendency in another.

These graphs (Fig. VII) illustrating the annual performance of individual bushes of Baldwin, are fairly typical of all the varieties. A general view would seem to suggest that differences of location would account for a good many of the extreme variations. But there remain enough cases of alternate high and low yields from individual bushes to suggest the possibility of a tendency to biennial bearing. This hypothesis receives some support from the last column of Table VIII. It will be observed that, when the crops for 1922, 1923 and 1924 from the individual bushes are added up separately, there is a pronounced reduction in the probable error (expressed as a per cent.), which presumably implies a smoothing out of the variability. So far as we are aware this is the first instance in which such a tendency in small fruits has been pointed out.

The Economic Interpretation of the Figures.

What then is the value of these figures to the grower, and their interpretation as a guide to the cropping powers of the varieties? We have already said that an increase of 10 per cent. on a crop of 1 ton per acre of black currants would even in 1924 have brought in an increased gross return of £6 per acre. Consider now the meaning of the average figures in Table II, and the complement, showing their significance, in Table VII. The outstanding feature of these trials is the comparison of Baldwin with any other variety; out of sixteen possible comparisons twelve, according to our severe test, show a significant difference (though not necessarily to the exact extent shown) in favour of Baldwin, and in three of the other four cases Baldwin actually gave a heavier crop, leaving but one comparison unfavourable to Baldwin, and this in the exceptional year 1924. Now let us go on to see how much superior was its cropping power, and the increased economic return thereby produced.

Table XI shows the figures in the last column of Table II worked out on the basis of cwts. per acre per year.

Table XI.

Average Crop per acre per year, 1922, 1923, *and* 1924 *together.*

	cwts.
French	27.8
Seabrooks	29.2
Boskoop	32.9
Goliath	32.9
Baldwin	41.6

This superiority of Baldwin under our conditions would have given a gross increase over any other variety of not £6 per acre, but, at the 1924 price (the lowest of recent years), £26 per acre per annum.* Nor is this all. Not only could the Baldwin bushes have been planted much closer than those of other varieties on account of their comparatively dwarf growth (our figures are based on a distance of 5 ft. by 7 ft. 6 ins. for all varieties), but we have invariably been able to get a higher price for the fruit of Baldwin than for that of any other variety (sometimes double the price made by the fruit of Boskoop) largely owing to its lateness. Further, the yield of Baldwin was proportionately higher in the early years than later, giving a more prompt return on investment.

This point of early return, as shown by the figures in the 1921 and 1922 columns of Table II, is of more importance than is often realised. When we first examined these figures, we were inclined to think that they were (except in the case of Baldwin) largely a matter of chance. But they so strikingly confirm the results of our earlier series of variety trials that we consider the whole point worth discussing at some length.

In each trial, the crop of Boskoop and Goliath, in the first year or two, was markedly lower than that of French, Seabrooks, or of course Baldwin. In each trial, also, as the bushes developed the crops of Boskoop and Goliath overtook and passed those of French and Seabrooks.

This delayed cropping agrees so well with the known habit of the varieties Boskoop and Goliath—strong growth, especially in the early years—that we are inclined to think it is characteristic of the varieties, in the same way as certain strong growing varieties of apple, such as Bramley, are characterised by slow cropping. If such a behaviour can be traced in particular varieties of small fruits, it may be of considerable economic importance, since small fruits are so often planted with the object of getting quick returns. For instance, we find Baldwin, in the second year from the planting of one year rooted cuttings, cropping at the rate of 4 cwt. per acre, and a year later 1 ton per acre, compared with, say, Boskoop, which yielded less than 1 cwt. and nearly 11 cwts. per acre in the same years.

Regarded from the point of view of early return on capital, this fact adds greatly to the already superior value of Baldwin in our conditions.

In our earlier attempt to allow for this factor (Annual Report, East Malling Research Station, 1922), we took the crop of Baldwin as 100 in each year and the others in proportion. It is now clear that this seriously overweights the value of the earlier crops.

* Although Table VII shows these differences to be significant, and the cropping power of Baldwin in 1922, 23 and 24 to have been greatly superior to that of other varieties, it must not be thought that one could expect to obtain an identical difference on repetition of the experiment under similar conditions. Table VII merely indicates that we could expect a considerable difference in the same direction.

We propose instead the following basis. We deduct each year, from the gross value of the crop, a rough estimate of expenses, including: interest on investment £1 10s., rent £4, other expenses, year of planting and first cropping year £20, second cropping year £30, later years £40 per acre. Although these figures may be criticised as too high or too low, we must point out that the actual figures do not affect the principle involved, and are chosen without very accurate verifications, merely to illustrate the point.

Taking these estimates, and the value of the crop, as before at £60 per ton, we get the figures in Table XII.

TABLE XII.

Net return in £'s per acre after deducting rough estimate of expenditure *

Cropping year:	1st. 1921.	2nd 1922.	3rd 1923.	4th 1924.	Net profit per year from planting.
French ..	£19 6s. *loss.*	£3 6s. *loss.*	£4 10s. *loss.*	£130 18s. *profit.*	£15 13s.
Seabrooks	£17 13s. *loss.*	£7 6s. *loss.*	£5 18s. *profit.*	£136 14s. *profit.*	£18 9s.
Boskoop ..	£23 0s. *loss.*	£3 14s. *loss.*	£1 14s. *profit.*	£170 14s. *profit.*	£24 2s.
Goliath ..	£23 7s. *loss.*	£2 10s. *loss.*	£24 10s. *profit.*	£147 18s. *profit.*	£24 4s.
Baldwin ..	£13 10s. *loss.*	£24 6s. *profit.*	£88 14s. *profit.*	£153 18s. *profit.*	£45 12s.

We would only repeat that even these figures, which hardly need further discussion, make no allowance for the closer planting possible with Baldwin, or the higher price actually obtained for its fruit.

Finally, we ought to say that we have as yet no evidence of a shorter profitable life on the part of Baldwin than of other varieties, provided the bushes are given reasonable care.

In conclusion we wish it to be understood that by dwelling upon the superior performance of Baldwin under our conditions we are not intending to give it an unqualified testimonial. Our real object is to emphasise the supreme economic importance of varietal characteristics under any given conditions, and the absolute necessity for the repetition of such trials under conditions differing from our own, yet with at least as great a measure of control.

SUMMARY.

1. Individual bush records from plots of sixty to seventy bushes of five varieties of black currants show that, apart from the first cropping year, the probable error of the average crop of a variety in each year is approximately 2 per cent.

2. Of forty possible comparisons between pairs of varieties, only thirty-one significant differences are revealed, even when each plot comprises sixty to

* We wish it to be understood that we are not putting these figures forward as an indication of the possible profits to be made from black currants. They are merely presented as a *measure of relative value*.

seventy bushes. Smaller plots would have given correspondingly fewer significant differences.

3. The conditions which contribute to the variability of bushes are considered. These include seasonal differences and cultural practice. Pruning has materially increased the variability of cropping power among individual bushes in the same season.

4. From the results obtained, a table is deduced which shows the number of bushes required to detect a given difference, and conversely, what difference can be adjudged significant when the plots contain a given number of bushes.

5. Indications have been obtained that there may be a tendency towards biennial bearing in black currants.

6. The average crop figures for three years place the five varieties in the following order :—

Baldwin,	1.
Goliath, Boskoop,	2.
Seabrook's, French,	4.

7. The comparative economic value of the five varieties has been deduced from the records by applying ruling prices and arbitrary expense figures.

APPENDIX.

Crop Records of Individual Bushes of FRENCH.

Bush No.	1921. oz.	1922. oz.	1923. oz.	1924. oz.
1	—	—	—	—
2	2½	19	14	54
3	1½	15	19	—
4	3	20	22	80
5	2½	20	25	97
6	1½	16	28	104
7	1	11	24	73
8	1	20	16	89
9	—	—	—	—
10	1	24	32	118
11	1½	24	31	104
12	1½	24	34	—
13	1	24	28	99
14	2	20	30	119
15	3	13	24	89
16	½	12	24	90
17	½	17	15	92
18	1½	—	—	—
19	3	13	15	90
20	1	13	23	88
21	4	18	20	106

Bush No.	1921.	1922.	1923.	1924.
	oz.	oz.	oz.	oz.
22	4	15	24	90
23	2½	17	30	80
24	4	12	16	85
25	1½	17	20	82
26	2½	15	19	80
27	1	13	32	104
28	2	15	18	79
29	2½	12	17	68
30	3	17	23	84
31	4	20	21	89
32	2½	9	21	72
33	2½	12	19	92
34	1	15	20	101
35	4	16	32	92
36	2½	5	—	—
37	3	16	20	90
38	2	24	23	98
39	4½	28	25	97
40	1½	12	18	75
41	2½	16	16	68
42	1	13	24	85
43	6	16	28	102
44	4	14	12	—
45	4	12	18	89
46	2½	8	19	85
47	3	15	18	111
48	4½	14	24	92
49	4	16	28	88
50	4½	18	18	96
51	3	16	17	80
52	6	17	18	88
53	3	12	—	—
54	4	16	24	114
55	5½	13	20	94
56	½	12	12	56
57	2½	12	10	96
58	3	5	—	—
59	4	16	12	74
60	4½	16	17	69
61	6	17	20	80
62	3½	14	20	96
63	4	16	16	101
64	4½	—	—	—
65	3½	17	12	104
66	3½	10	5	65
67	4½	17	17	66
68	2½	14	17	—
69	4½	15	15	92
70	—	17	16	77
71	—	20	28	—
72	4	24	16	92
73	2½	17	16	68

THE BLUE STRIPE WILT OF THE RASPBERRY.

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I. Introduction.

A disease of the cultivated Raspberry (*Rubus Idæus L.*), hitherto unrecorded for this country, was brought to the notice of the present writer in the winter of 1923-24. All the varieties (collected from various sources) grown in the trial plots at the East Malling Research Station showed at least a trace of the disease, while some varieties were affected to such a degree that the results of the trials were being seriously impaired and an investigation of the disease was imperative.

The wood and pith of diseased canes collected during the winter were found to be infested with delicate fungal hyphæ and particles of the wood and pith transferred to agar plates yielded with marked purity and regularity cultures of a fungus which was identified as a species of *Verticillium.* Later (in spring and early summer) other organisms were isolated from diseased fruiting canes, but no one organism appeared with the constancy shown by this species of *Verticillium* which was isolated from many varieties of Raspberry and over a considerable period of time. That this fungus is the cause of the disease was shown by the inoculation of seedling plants from plate cultures of the *Verticillium* when the characteristic symptoms of the disease (described below) were induced under adequately controlled conditions.

No fructifications of the fungus have been observed on diseased canes and roots under field conditions, but they were readily produced under moist artificial conditions in the laboratory. In the winter, however, minute black resting bodies (microsclerotia) were observed in large numbers embedded in the tissues of the bark of infected canes of several varieties, which, on transfer to agar plates gave rise to cultures of a *Verticillium* similar to that isolated from the diseased wood and pith. These sclerotia, therefore, probably function as reproductive bodies.

This disease, with respect to its effect on the cane and on the fruit, has many points of resemblance with the "Blue Stem" disease of the Black Raspberry (*Rubus occidentalis L.*), described by Lawrence (5), a striking feature in both cases being the appearance of a blue colouration of the cane which sometimes takes the form of a stripe. Lawrence refers the suspected parasite to the genus *Acrostalagmus* Corda, and proposes a new species *Acrostalagmus caulophagus.* More recently Carpenter (2), concludes that this species "must be regarded as belonging to the genus *Verticillium.*" Lawrence appears to be the only worker who has

published, in any detail, an account of the " Blue Stem " disease as occurring in America, though brief references to the disease have appeared from time to time (1, 3, 4, 6, 7). Lawrence isolated what is probably the causal organism, but carried out no inoculation experiments for confirmation.

II. Field Observations.

The chief points of interest arising from observations extending over one year, carried out over the collection of varieties on the trial plots at the East Malling Research Station will now be dealt with in some detail in order to provide sufficient data for the recognition of the disease in the field.

(1) *Symptoms on the Fruiting Canes.*

The only indication of the disease during the winter was the presence of dead canes with shrivelled ill-developed buds. The diseased condition was thrown into strong relief, however, when the canes came into leaf in the spring. The dead canes then became very conspicuous and, in addition, some canes were seen to be partially affected by the disease from the failure of a proportion of buds on the canes to burst. These dead buds were found to occupy nodes lying in the same vertical line, thus destroying the radial symmetry of the cane. On sectioning such canes a discoloured strip of wood was found corresponding to the nodes bearing the dead buds, the remainder of the wood being normally green. The proportion of wood thus found affected in the spring, varied greatly.

As the leaves appeared and the lateral fruiting branches grew out, some canes were conspicuous for the dwarf character of their leaves and the poor development of their fruiting laterals. In some of these cases the cane lived to produce under-sized, woody, tasteless fruit, and in others the leaves soon became yellow and withered, and the cane died before the fruit was matured. Other fruiting canes were noted which did not show symptoms of disease until some time after they had come into leaf. There was great variation in the stage of development of the fruiting canes at which the first symptoms of disease were shown, and in the rapidity and extent of the subsequent progress of the disease in the cane. Thus some canes, apparently healthy as the leaves unfolded, soon afterwards showed symptoms of attack and in a short time their leaves became yellow and withered. In other cases the symptoms did not appear until the fruit approached maturity; in these cases the leaves became prematurely discoloured and withered, followed by a withering of the fruit and the death of the canes.

The distribution of diseased fruiting canes in the row varied. In some cases only a small proportion of canes or only one cane of a stool showed symptoms of

disease but often all the canes of a single stool would show the disease to a greater or less degree. Some cases were noted in which all the canes of a stool were affected to an extreme degree, the canes being dwarfed and ill-developed in every way, and producing no fruit or small, woody, discoloured, tasteless fruit. Stools with all the fruiting canes dead were by no means uncommon. Such severely infected stools generally produced but little new cane and " spawn."

(2) *Symptoms on the New Canes.*

The most characteristic symptoms of the disease are those which appear on the new canes (or current year's canes). These symptoms, however, do not appear until comparatively late in the season. Thus until just before cropping time stools were observed whose fruiting canes showed symptoms of disease, but whose new canes appeared normal.

The first case of symptoms of disease in the new canes was observed at the end of June on a variety very susceptible to the Wilt (Red Antwerp A.*). A stool was noted with three canes, all very dwarfed. One was a fruiting cane, and showed discoloured and wilted leaves, and such fruit as was present was very under-developed. The remaining two were new canes and were conspicuous on account of a dark blue discolouration of the cane ; in one case there was a distinct blue stripe extending upwards from ground level, while in the other, this blue colouration was at first dense in patches and thinned out in places. The continuity of the discolouration from ground level, could, however, be traced in both cases. On both canes the leaves had wilted and withered, apparently quite suddenly, for they were still greenish in colour, although dry. On examination in the laboratory, the outer wood vessels of these new canes were seen to be infested with delicate mycelium characteristic of the *Verticillium*, and most of the hyphæ appeared to be extending in an upward direction rather than laterally. There were no hyphæ in the pith. On transferring sections made at various points on these canes to agar plates the *Verticillium* grew out in a pure condition.

This was an early case of what became quite general as the season progressed, and similar symptoms were observed in a large number of different varieties. From every new cane examined, showing the blue stripe symptom, the *Verticillium* was isolated, generally in a pure condition. In the autumn, however, it became necessary to distinguish the blue stripe as a symptom of the wilt disease, from the ripening colouration of the cane. The blue stripe was observed to work up the cane from ground level and was continuous, whereas change of colour due to ripening, often took place irregularly in patches. The limits of the stripe were very sharply defined and usually ran in a vertical line,

* The classification followed here is that of Grubb in " Commercial Raspberries and their Classification," Journal of Pomology. Vol. III., No. 1. November, 1922.

so that there was a sharp contrast which was not obliterated even when the ripening colour had appeared as well. In a few varieties such as *Bath's Perfection*, the stripe was dark blue-brown in colour, but in most cases the blue colour was unmistakable. In fact, this blue stripe effect was found to be the most reliable symptom for the diagnosis of the disease in the field and suggested as a descriptive name the " Blue Stripe Wilt of the Raspberry."* On sectioning new canes with the blue stripe, a sector of the wood corresponding to the stripe on the surface was invariably seen to be more or less discoloured. Many of these canes, particularly those showing the blue-stripe earliest in the season, were, later, completely girdled, all of the wood becoming discoloured, and the whole cane conspicuous for its dark blue colour. Such canes soon died.

The effect of the disease on the leaf of the new canes was not as a rule so sudden and complete as in the particular case described above, but could often be observed long before the " stripe " appeared on the cane. In fact the characteristic leaf symptom was often the first sign of infection in a new cane. The lower leaves of the cane were always the first to be affected. The tissues of the lamina lying midway between the main veins became yellow or red-brown, the colour varying in different varieties. This colour change became increasingly accentuated and finally these interveinal tissues withered, the tissues immediately around the main veins retaining their green colour for a considerable time, so that the leaf had a characteristic striped appearance (Plate XI, Fig. 1).

A point which distinguished this phenomenon from autumn discolouration was that often only a part of the leaf was striped. Thus leaves were observed in which one half of the terminal leaflet (limited by the midrib) was striped, and also the entire lateral leaflet on the same side of the stalk, whilst the other half of the terminal leaflet and the corresponding lateral leaflet were quite green and normal (Plate XI, Fig. 2). Later, the effect spread by degrees to these unaffected parts. The striping of the leaves was often accompanied by a withering and upward curling of the margin or part of the margin of affected leaflets and ultimately such leaves fell prematurely, the leaflets generally being cast independently and the petiole remaining attached to the cane for some time. The symptom described above forms one of the most striking features of the disease. The under surface of the leaves, being nearly white, shows up, on these leaves with the upward curled margin, in clear contrast to the dark, striped upper surface.

The terminal tuft of leaves was invariably the last to be affected and often survived the rest of the leaves for a considerable time, so that the spectacle of new canes denuded of their leaves with the exception of the tuft of latest formed leaves was quite common. Cases were also noted where the leaves arising from

* This as a descriptive name is perhaps preferable to Lawrence's term " Blue Stem Disease," since in some varieties of our red raspberries a general bluish colouration appears on the new canes towards the end of the season in the absence of any evidence of the Wilt Disease.

Fig. 1.

Fig. 2.

PLATE XI.

nodes in the same vertical line were affected in advance of the others, a condition obviously corresponding to that observed on those fruiting canes whose buds were killed in vertical lines. The appearance of the blue stripe (which, from results obtained from cultural work, indicated the extension of the fungus into the aerial parts of the cane), often did not take place till all the leaves had shown the stripe and wilting symptoms and had been cast. Sometimes, however, it appeared at an early stage and the rapid death of the affected cane took place.

Numbers of canes showing initial symptoms of the disease (i.e., leaf striping), were labelled and kept under observation. The majority of these canes eventually showed the later symptom of the disease and the *Verticillium* was isolated from a number of them. In some cases this appearance of the *Verticillium* in the cane with the accompanying discolouration of the wood vessels was delayed until late Autumn and early Winter.

It will be seen from these observations on the new canes, that, as with the fruiting canes, there was great variation in the rapidity with which the disease symptoms followed each other in different canes, and in the severity of attack. The final killing of the whole or part of individual canes, generally, though not always, took place in late Autumn or early Winter.

(3) *The Distribution of the Disease and the Seriousness of Attack.*

About a hundred varieties of Raspberry in the collection at the East Malling Research Station have been examined from time to time, and notes made as to the incidence of the disease. In no case was a variety found completely free from the disease, but the severity of attack varied greatly with the variety. In some varieties it was negligible but in many, among which were varieties of commercial importance, the effect of the disease was considerable, both on the fruiting canes and on the new canes. In such varieties it was noted that the severely diseased stools were usually adjacent to one another in a row which consequently had a " patchy " appearance.

Among the varieties most seriously affected at East Malling the following might be mentioned :—

Bath's Perfection.
Red Antwerp B.
Prior's Prolific.
Mitchell's Seedling.
Red Antwerp A.*
Baumforth A.
Baumforth B.
Reader's Perfection.

* Black Antwerp A. although almost indistinguishable systematically from Red Antwerp A. is one of the least seriously attacked varieties here.

To obtain a numerical measure of the severity of attack on the new canes in one instance, counts of diseased and healthy new canes were made in September over fifty consecutive stools of a row of the variety *Bath's Perfection*, which under our cultivation conditions is very susceptible to the disease. The proportion of the total new canes showing definite symptoms of disease was 40 per cent.

There is reason to believe that the disease is widespread for its characteristic symptoms have been noted in other localities. The *Verticillium* has also been isolated from specimen canes sent from Surrey and Sussex.

A more extensive survey of the incidence of the disease on different varieties and in different localities has been planned for the future, and the writer would be interested to hear from growers and others who have noted the disease and would welcome specimens and information relating to varieties affected and extent of injury caused.

III. Inoculation Experiment.

An attempt to induce the symptoms of the disease by artificial inoculation of healthy plants with the fungus suspected of causing the disease, was made at the end of July, 1924.

Seedling plants (consisting of one slender leafed cane) raised from seed obtained the previous summer from "selfed" flowers of the *Lloyd George* variety, were employed for this experiment. These were grown in three pots, three plants in one pot, and two in each of the others. One plant in each pot was kept as a control and the remainder inoculated, each at a point above and below soil level. There were thus four plants inoculated and three controls.

The inoculations were carried out by introducing into small holes bored in the stem, mycelium from agar plate cultures of the *Verticillium* isolated from infected canes by the direct transference of diseased tissue to the plate.

The observations made on the progress of the disease in the inoculated seedlings, are summarised in the accompanying table in which the three pots are referred to as A, B, and C respectively. From this table it will be seen that, of the four seedlings inoculated, all developed, sooner or later, symptoms of disease closely corresponding to the symptoms observed in the field, and three of the four were completely killed. From these three seedlings the *Verticillium* was re-isolated. All the controls remained healthy.

The rapid progress of the disease in the inoculated plant in pot B, is illustrated in Plate XII, Figs. 1 and 2, and Plate XIII, Fig. 1. Plate XII, Fig. 1 was taken on the day following that on which the symptoms of disease were first detected (thirty-four days after inoculation), and Plate XII, Fig. 2 and Plate XIII, Fig. 1 at intervals of five and nine days respectively. Plate XIII, Fig. 2 shows part of the cane of the inoculated plant as shown in Plate XII, Fig. 1, and shows

Fig. 1.

Fig. 2.

PLATE XII.

Fig. 1.

Fig. 2.

PLATE XIII.

the upper point of inoculation protected by cotton wool, the blue stripe extending upwards and downwards from this point, and the semi-detached petioles in its neighbourhood, also striped.

Although the number of plants available for inoculation was small, the results as seen in the table and in the figures are sufficiently striking to warrant the conclusion that the species of *Verticillium* isolated with such constancy from diseased canes and used in these inoculations is the parasite causing the disease described in this paper.

IV. Aim and Scope of Work in Progress.

At this stage not enough is known of the life-history and physiology of parasitism of the fungus in its relation to the raspberry to enable reliable methods of control to be recommended.*

Field observation work is being continued with special reference to the relation between severity of attack, the variety of raspberry attacked, methods of cultivation, and locality conditions.

In addition, experimental plots have been planned to facilitate the study of the relative importance of different sources of infection in their relation to the incidence and spread of the disease, also the degree of dissemination of the disease by various methods employed for the propagation of the raspberry, and the possibility of producing clean stock for planting up.

Meanwhile, as it has been proved that the disease is due to a fungus present in the underground system and in the canes of infected stools, growers and nurserymen are advised to raise their stocks from stools which show no symptoms of this disease.

SUMMARY.

1. A disease of the cultivated Raspberry causing a wilting and death of the canes, progressing from below upwards, is described, and the nature and extent of its damage to the crop discussed.

2. Cultural work with diseased material resulted in the isolation of a fungus of the genus *Verticillium*, with marked constancy, from affected stools of many susceptible varieties.

3. An inoculation experiment carried out under controlled conditions on seedling plants, using plate cultures of the species of *Verticillium* isolated from diseased canes, was successful in inducing the disease with its characteristic symptoms as observed in the field.

4. It is proposed for reasons stated to designate the disease by the descriptive title " The Blue Stripe Wilt " of the Raspberry.

* Further research in this disease is being carried out by the writer under a grant, made by the Ministry of Agriculture and Fisheries, to the East Malling Research Station, for research in Raspberry Diseases.

5. Temporary control measures are recommended pending further research along lines which are indicated.

In conclusion the writer wishes to express his indebtedness to the East Malling Research Station for facilities offered for the investigation of the disease, to Dr. H. Wormald at whose suggestion and under whose guidance the research is being carried out, and to members of the Pomological Staff for valuable help and co-operation in the field and propagation work.

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EXPLANATION OF PLATES.

Plate XI.
- Fig. 1. A " new cane " (var. Lloyd George), photographed Sept. 4th, showing initial wilt symptoms, i.e., collapsing and "striping" of lower leaves.
- Fig. 2. One of the lower leaves of the cane in Fig. 1, showing withering of interveinal tissues and curling of leaflets. Note, in this case, that the withering is more advanced on the right of the midrib.

Plate XII.
- Fig. 1. Pot B, of inoculation experiment thirty-five days after inoculation of plant on the left.
- Fig. 2. Plants shown in Fig. 1 but five days later: lower leaves of inoculated plant withered, terminal leaves drooping.

Plate XIII.
- Fig. 1. Plants as in Plate XII, Fig. 2 but nine days later: lower leaves of inoculated plant fallen, and terminal leaves withering.
- Fig. 2. Stem of inoculated plant as shown in Plate XII, Fig. 1 (nat. size): point of inoculation protected by cotton wool, above; dark stripes downwards and upwards from this point; petioles collapsing and becoming striped.

Table summarising observations on Raspberry Seedlings inoculated July 30th, 1924.

	POT A.			POT B. (moist conditions).		POT C. (under bell-jar).	
Date of observation.	Plant 1.	2. Control.	3.	1.	2. Control.	1.	2. Control.
September 3.	No disease symptoms.	No disease symptoms.	No disease symptoms.	Blue-stripe on cane; leaves yellowing, lower leaves detached, upper leaves healthy. (See Pl. XII, Fig. 1).	No disease symptoms.	Dark-stripe on cane. Some leaves detached, others drooping. Upper leaves healthy.	No disease symptoms.
September 5.	Do.	Do.	Do.	Blue-stripe rapidly extending and girdling. Sectorial yellowing and some withering of leaves.	Do.	Stripe extending slowly.	Do.
September 8.	Lower leaves yellowing.	No disease symptoms. Leaves all green.	Lower leaves yellowing.	As above, rapid withering of leaves. (See Pl. XII, Fig. 2).	Do.	Yellowing of leaves, Stripe extending.	Do.
September 17.	Lower leaves yellowing and withering sectorially. Lowest leaves detached. Blue-stripe on two petioles.*	No disease symptoms. A few leaves showing autumnal discolouration.	As in Plant 1.	All except terminal two leaves detached. Whole cane dark blue. (See Pl. XIII, Fig. 1).	Do. As in control of Pot A.	Stripe extending. All leaves except uppermost yellowing and becoming detached.	Do. As in control of Pot A.
October 29.	Blue-stripe has appeared on cane. All leaves detached except terminal four.	No disease symptoms. Normal leaf fall beginning.	Leaves still wilting. No blue-stripe.	Plant completely dead.†	Do. As in control of Pot A.	All leaves except uppermost three are detached. Sector of dead wood in cane.†	Do. As in control of Pot A.
November.	Cane completely dead. Shoot arising at ground level still living.†	No disease symptoms. Wood green.	Wood of cane still green.		Do. As in control of Pot A.		Do. As in control of Pot A.

* *Verticillium* re-isolated from these petioles.

† At this stage cane severed and *Verticillium* re-isolated from it.

BIOLOGICAL OBSERVATIONS ON APPLE "SCAB" OR "BLACK SPOT."

(*Venturia inæqualis*)

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In the spring of 1923, when spraying experiments were undertaken in a certain plantation of different varieties of apple-trees at Stonebridge Green Farm, Egerton, Kent, very early outbreaks of scab had been noticed on the youngest leaves of trees of the variety *Bismarck*, although no appreciable amount of the fungus had been previously evident on the young wood.

It was therefore decided to carry out in 1924 an early and critical examination of all the varieties in this plantation.* The discovery† in the spring of that year of the perithecial, or *Venturia*, stage of the fungus existing in this very plantation on fallen leaves of the previous season, provided a likely explanation for the early outbreaks, and so reduced the necessity for tracing the origin to the nearest scabbed wood, which until then had been regarded as the only means in this country by which the disease could persist from one season to the next.

Several visits were paid to the plantation during May, and in addition to a search for the occurrence of scab on young wood, observations were made on the relative susceptibility of the foliage of different varieties of apple to early attacks of scab, as well as on the intensity and mode of attack. Later inspections were also carried out at the beginning of June and early in August.

The question of varietal susceptibility is of particular importance in its relation to the adoption of control measures, because although it is known to most growers that varieties of apples behave differently as regards susceptibility to scab, there is in this country very little definite information as to the exact season when the attack may be found in its initial stage.

The plantation consisted of bush trees planted in 1915 at 14 foot square. The soil was a stiffish loam. The trees were moderately well-grown and had made a fair amount of wood growth and had cropped well during the last few years.

* We take this opportunity of thanking Captain E. D. Scoble-Hodgins for the facilities afforded.

† See *E. S. Salmon* and *W. M. Ware*, in *Gardeners' Chronicle*, LXXV, p. 190, Apri 5th (1924); and in *Journ. Min. Agric.*, XXXI, Sept. (1924).

The plantation appeared very suitable for biological observations. Firstly, it was known that severe attacks of scab had occurred during past seasons, and secondly, on account of the mixed planting and duplication of varieties with rows running the entire length, it was considered probable that liability to infection would be evenly distributed and relative susceptibility might therefore be more accurately gauged.

There were thirty-four rows, planted from North to South, consisting each of about forty-five trees; the actual number and the names of varieties in the order in which they were planted, are detailed in Table I, starting from the East side of the plantation.

The first examination was on the 1st May, when two rows of *Cox's Orange Pippin* were inspected, this being thought the variety most likely to be a source of early infection. On that date, the first leaves were just expanded. Of forty-one trees in one row (Row 12) only nine appeared to be free from Scab on their young wood and fourteen were severely attacked. Of forty-three trees in another row (Row 8), only five were free, and twelve were severely attacked.

A row of young standard *Bramley's Seedling* (Row 1) on the edge of the plantation was inspected and no trace of Scab could be found on the young wood of any of the twenty-one trees, though these were too tall for close examination of all the branches.

Between the 21st and 28th May, eighteen rows consisting of 654 trees of eight varieties were thoroughly examined and the presence or absence of Scab on the leaves noted. On each tree the intensity of attack and position of the fungus on upper or lower surface were recorded with a view to obtaining some information as to whether varietal peculiarities might exist. In all cases where the number of scab spots did not exceed ten, it was noted whether the affected leaves were those subtending a blossom truss, or those produced from ordinary wood buds; when the infection was greater it was considered that the attack had become general and the initial stage had been passed.

The counts made are summarised and recorded under the varieties in Table I. It will be noticed that there is considerable difference between the percentage numbers of trees showing scab. It must be borne in mind that at this time of the year the fungus was only starting its attacks and the numbers of trees showing the disease at that period, though not by any means to be regarded as the final estimate on which to base opinions regarding varietal susceptibility to scab throughout the season, nevertheless afford some indication that certain varieties may be already heavily infected by the middle of May, whereas others are comparatively free.

Differences between the figures for two or more rows of the same variety are probably due both to an insufficient number of trees on which to base the percentage calculation per row, and to the localised intensity of the scab attack

which was even to be noticed within any one row. Trees at the North end were as a rule more heavily attacked than elsewhere.* If the question of localisation of attack be eliminated, and all the rows of any one variety be grouped together, the differences between the percentage numbers of trees affected appear even so to be sufficiently wide to indicate that varieties possess different degrees of susceptibility to early attack. (See Table II.) This indication is not only supported by the numbers arrived at in the case of *Bismarck* and *Lane's Prince Albert*, where the eight rows alternated, but it is also supported by the fact that wherever a tree of another variety had been planted in any row (see column 4, Table I) its behaviour to scab attack was found to be different from that of the adjoining trees in the row. The following cases were noticed : *Bismarck* interplanted in *Lane's*, and *Beauty of Bath* in *Cox's*, in *Worcester*, and in *Bismarck*.

It is clear from the observations made in this plantation, that early in the season, the varieties *Cox's Orange Pippin*, *Worcester Pearmain* and *Bismarck* were readily attacked by the scab fungus, whereas *Newton Wonder*, *Beauty of Bath*, *Bramley's Seedling*, *Lane's Prince Albert* and *Annie Elizabeth* were more resistant. This is borne out by the great number of trees in the class (column 9, Table I), where eleven or more spots of scab were found, in the case of the first three varieties above mentioned.

It would seem that in the case of trees producing bloom, the first attacks of the scab fungus, whether originating from ascospores or from the conidial (*Fusicladium*) pustules on affected wood, start on the small leaves subtending a blossom truss. (See Plate XIV.) The secondary leaves on the wood become infected in succession as they unfold, by conidia arising from the infection of the older leaves, or by ascospores from dead leaves on the ground, or by conidia from the pustules on infected wood.

During the last three weeks of May, 1924, this attack on the subtending leaves was noticed on all the varieties under consideration, with the exception of *Annie Elizabeth* ; the intensity, however, was very variable. The " spotting " recorded in columns 7, 8 and 9 of Table I was almost entirely confined to these primary leaves and during May it was the exception to find scab on the younger foliage of the elongating wood-buds.

On the 21st May, when the variety *Bismarck* was still in flower but blossoming was nearly finished, it was noted that a considerable number of the leaves round the spurs were heavily infected and a microscopical examination showed that conidia were being produced in abundance. In several cases the scab had killed the underlying tissue and brown, dead spots showed through to the other surface. Crinkling and curling of the leaf, due to scab, was also

* This may possibly be explained by supposing that prevalent Southerly winds had blown the dead scabbed leaves of the previous season to the North end of the plantation, resulting in a greater intensity of attack by ascospores.

observed. Notwithstanding this amount of infection, the trees would have been passed by a grower as quite healthy, none of the younger leaves on the shoots showing as yet any sign of disease.

On *Worcester Pearmain* (26th and 28th May) it could be said that the old leaves round the fruit-spurs were commonly infected ; in one case all the six leaves on one spur showed numerous scab patches in the sooty condition, i.e., producing conidia in abundance. On the 26th May the trees were just out of flower.

Although by 26th May the scab attack on the first-opened leaves was very evident in the case of varieties heavily infected, a much more careful search was required on the leaves of others, such as *Lane's Prince Albert*, where, by that date, the mycelium was only just beginning to spread and was difficult to distinguish on the dark, shiny, upper epidermis. This variety was in full flower on 21st May. Scab infections on *Bramley's*, noted on the 27th May, when the blossom had just fallen, were few in number (see rows 1 and 9, Table I) and were practically confined to the leaves round the spurs. The first spot of scab seen on *Bramley's* was on a leaf of a standard tree (Row 1) on 21st May. By the 1st June this particular spot had increased slightly in area and scab on that date was also found on another older leaf and on three young leaves of the same tree. On *Beauty of Bath* (just out of flower on 26th May) the number of scab spots was not great ; it was clear, however, that the attack had become established on the spur-leaves. On the 22nd May, when Row 12 (*Cox's*) was examined, the blossom was scarce and only half open. Even at that time, the first leaves were frequently sooty with scab. *Newton Wonder* on 28th May was shedding the petals and with this variety also the infection generally was on the oldest leaves.

With reference to these first-opened leaves, no difference could be distinguished between varieties in regard to the occurrence of scab on the upper or lower surfaces of the leaf and within any one variety it was found that both surfaces might be affected ; the majority of spots, however, were found on the lower surface.

If it be supposed that original infection was also caused by ascospores proceeding from dead leaves on the ground, it is interesting to note that the first spots found on 21st May were at various heights from the ground. Thus on the standard *Bramley's* at about 8 feet, on *Beauty of Bath* (Row 3) from 18 inches to 7 feet. On *Newtons* it was noticed that a quantity of foliage was produced low down in the tree, actually filling up the forks of the lowest branches from the "stem" at 1, 2 or 3 feet from the ground. It was mainly on this low-growing foliage that scab spots were found on 28th May, and most frequently on the lower surface of the leaves.

After inspection of all the rows, however, there was no evidence that infection started only on the lowest leaves. As it seems reasonable to suppose

that ascospores can be carried on the wind as easily to a height of 20 feet as to 20 inches and that a certain amount of scab (*conidia*) might also be proceeding from rows 8 and 12 (*Cox's*), the higher foliage would be equally liable to be infected early, as indeed was found to be the case.

In order to obtain some information as to the relative extent to which the different varieties would finally become scabbed when, as in this plantation, no spraying was carried out,* a general and rapid survey of some of the rows was made on 9th June and of the whole plantation on 11th August. In the latter case, the relative quantity of scab present in each row was indicated by marks 0—4, where 0 represents only a trace of scab and 4 a really heavy attack with the leaves blackened and curled up. These figures will be found in Table I. On 9th June, it was found that on *Beauty of Bath* (Row 3) the young leaves were beginning to become scabbed and in Row 13 they were even "sooty" on a few trees at the top of the plantation. *Cox's Orange Pippin* (rows 8 and 12), except for a few trees about the middle of the rows, showed general infestation. Scab was present on the young leaves sometimes in the "sooty" condition, as well as on the old. On *Worcester Pearmain* (Rows 6 and 11) scab was generally distributed through the rows and was commonly present on young leaves. The same variety in row 16 was less infested but the attack had there reached much the same stage and even the young leaves, as in rows 6 and 11, were to be found in the "sooty" state. The foliage of this variety was not quite so much scabbed as that of *Cox's Orange Pippin*. *Bramley's Seedling* (Row 9) was found on the whole to be comparatively free from scab on the young foliage. Very occasionally one or two spots could be found on younger leaves and as an instance of the unceasing attack of scab, whether from an outside source or from infected leaves on the same tree, it was noted in one case that even the second from youngest leaf was infected. This variety was a great contrast to the rows of *Worcester* and *Cox*, and to a less extent to *Beauty of Bath*, in that the young foliage was as a whole healthy.

Only a few spots of scab were found on the young leaves of *Newton Wonder* (row 10) and only on the trees at the top of the plantation (North end). The infestation was not so bad as on *Worcester Pearmain* or on *Beauty of Bath*. Trees of *Lane's Prince Albert* (row 28) appeared to be very unequally attacked. On some, the young foliage was, like that of *Bramley's*, almost or quite healthy, on others where a few spots were found, the attack did not appear to be progressing strongly. The scab patches were never very vigorous or black and gave the impression of being unable to thrive. The areas of leaf affected, turned yellow or brown in some cases and seemed to be killed.

Further examination of the young wood was carried out early in 1925. On the 7th April, when the plantation was visited, the buds of most varieties

* Except on three rows of *Bismarck*.

PLATE XIV.

"PINK-BUD" STAGE, AT WHICH THE FIRST ATTACKS OF "SCAB" (SEE ARROWS) COMMONLY OCCUR ON THE LEAVES SUBTENDING THE BLOSSOM-TRUSS.—Ecklinville, May 8th, 1924.

had swollen and showed signs of opening, and the young wood was exposed and easy to examine. Pruning in this plantation had been left to the last and there was consequently abundance of young wood from which conclusions might be drawn as regards scab susceptibility.

Cox's Orange Pippin, rows 8 and 12, bore scab pustules on practically every shoot of last year's growth, though the " leaders " at the top of the trees were occasionally quite free. Sections of the pustules showed that conidia were present, though the fungus had only rarely broken through the bark.

On *Beauty of Bath*, row 7, no scab pustules were found (except on one tree where a single shoot was affected).

Worcester Pearmain, rows 6 and 11, was most heavily attacked in the upper parts of the rows (North end). Although the amount of scab on any single twig was found to be almost as great as in the case of *Cox's Orange Pippin*, the total number of diseased shoots on any tree of *Worcester Pearmain* was considerably less. The trees gave the impression of being badly scabbed, though no scab pustules were found exposed. Specimens of shoots, removed and examined in the laboratory, showed mycelium gathered beneath the epidermis on the periphery of the " blister " or at its summit, and conidia were present in a few cases. In the lower part of the rows, scab was scarcer and even rare ; one tree was not attacked in row 6, and five trees in row 11.

On *Newton Wonder*, rows 5 and 23, no scab was found. On one tree small swellings were noticed, but specimens examined in the laboratory showed no mycelium at these " blisters."

The young wood of *Bismarck*, rows 27, 29 and 31, was found, in the upper part of the rows, to be free from scab, but at about half way down row 27 one tree was noticed on which two shoots were bearing pustules discharging conidia. The remaining trees were affected with occasional inconspicuous swellings on the shoots and specimens of these were removed for microscopical examination. In addition to mycelium and conidia beneath the unbroken epidermis, a few mature open pustules were found.

No scab could be found on the wood of *Bramley's Seedling*, row 4 ; a few shoots bore small unburst swellings in which no mycelium could be detected on microscopical examination.

Owing to the fact, recorded earlier, that the intensity of scab attack on the leaves of these different varieties had been kept during the previous season the above observations are of value in demonstrating that a heavy infestation of the foliage does not necessarily lead to the infection of the young wood.

SUMMARY AND CONCLUSIONS.

From observations made (not only in the plantation described) it is certain that attacks of " scab " may occur very early in the season. Also, that some

varieties appear to be more susceptible to early attacks than others and the degree of susceptibility appears to be continued throughout the season. In making this statement, the assumption is made that liability to attack was evenly distributed in the plantation. From the arrangement of the rows (see Table I) this assumption seems justified, at any rate in so far as later attack is concerned, because varieties such as *Cox's*, *Worcester Pearmain* and *Bismarck* provided from all quarters a plentiful supply of summer-spores for infection of other varieties throughout the season from the end of May onwards.

The attention of the fruit-grower needs to be drawn to the fact that with certain varieties a severe infestation of " scab " may occur on the leaves before the blossoms open. Owing to the fact that the primary leaves are small and partially hidden by the blossom trusses, a heavy infestation may easily pass unnoticed by the grower. The secondary leaves, when they have expanded are larger and more conspicuous, and though they may be promptly infected, they remain apparently healthy for a week or two until the fungus has had time to grow under the cuticle and to develop spores on the surface of the leaf. By this time the disease will probably appear in certain places in a plantation or orchard, in epidemic intensity, and the opportunity of applying a protective fungicide will have been missed. To spray apple-trees against scab before the blossoming period is a comparatively rare practice for the commercial fruit grower in this country. Yet it appears quite certain that a " pre-blossom " spraying is as necessary here in order to protect certain varieties of apples from " scab " as it is in Canada and in the United States, where such early applications are becoming an established routine operation.

The very unsettled weather conditions which often prevail in England at the end of April and beginning of May undoubtedly make spraying at that time of year an operation very difficult to carry out satisfactorily. It must be remembered, however, that it is the same weather conditions, (viz., frequent showers or mists when apple leaves are wetted and remain so for some time) which make spraying difficult which also provide the optimum conditions for heavy scab-infections to take place. The experiments of Aderhold and others have shown that the spores of the fungus are absolutely dependent upon drops of water for their germination processes. These spores appear to proceed usually from two sources in the plantation or orchard ; from pustules of summer-spores occurring on the " scabbed " young wood of certain varieties, and from winter-spores (*ascospores*) discharged in great numbers* from the dead, scabbed leaves of the previous season which are lying on the ground. Recent work in

* Errett Wallace, an American investigator, found that from a fragment of leaf 1 cm. square, 5,630 spores were discharged in forty-five minutes. From this it was computed that " if the surface of the ground beneath the trees set 40 by 40 feet apart were covered with old leaves well infested with perithecia, there might be 8,107,200,000 ascospores discharged for each tree in forty-five minutes in wet weather."

the United States by Keitt and Jones* has shown that the major portion of the season's discharge of ascospores may take place in early spring before the flowering of the apple-trees.

The writers' observations† have shown that in this country the perithecia are mature and ready to discharge their spores considerably before apple-leaves begin to unfold, and continue in this state throughout the spring months.

It is highly important that varieties such as *Bismarck*, which are liable to become infected on the leaves produced before blossoming time, should be sprayed at the " pink bud " stage of growth. If the grower by watching the weather and by having all ready for the operation is able to accomplish this spraying on the few fine days in a wet spring, he can feel assured that such spraying (followed by others) will protect the crop of apples from the exceptionally severe attacks of scab which would otherwise spoil it in such a season.

It was noticeable in the season of 1924—the worst year within memory for severity of attack of apple scab—that the growers who grew the cleanest crop of apples were those who had made a practice of spraying their trees, or at least certain varieties, before the blossoming period. Independent testimony of the value in 1924 of this early spraying was supplied by two farmers in Kent, one in the Maidstone district and the other near Canterbury, who both noticed that " scab " was severe in their plantations only on those trees where either the bad weather had prevented the application of the early spray or where rain had washed it off before it had dried on the leaves.

It is a matter of great practical importance for the grower to know which varieties are most susceptible to heavy infection *earliest in the season.* If there is not time (owing to bad weather conditions) for all the susceptible varieties in a mixed plantation to be sprayed in the pink-bud stage, the grower can then concentrate on the most susceptible and prevent them from becoming infested and a source of infection to the other varieties. Thus, in the plantation in question, the varieties *Cox's Orange Pippin*, *Worcester Pearmain* and *Bismarck* would require this special early attention, whereas the more resistant varieties such as *Lane's*, *Beauty of Bath*, and others might be left until the later foliage had unfolded just after blossoming.

* Phytopathology, XV, p. 57 (1925).

† *E. S. Salmon* and *W. M. Ware, in Journ. Min. Agric.*, XXI, Sept., 1924, and XXXII May (1925).

TABLE I.

Occurrence of Apple Scab in the Plantation at Stonebridge Green, Egerton, Kent: May-August, 1924.

Varieties arranged in the order of their planting, from East to West.

Variety.	Row No.	Number of Trees								Intensity of Scab Infection Aug. 11, Classes 0-4.*
		in Row.	of other varieties.	actual total.	free from scab.	with 1-2 spots of scab.	with 3-10 spots of scab.	with 11 or more spots of scab.	% showing scab.	
Bramley's Seedling ..	1	21	0	21	20	1	0	0	4.8	1
Annie Elizabeth ..	2	45	0	45	45	0	0	0	0.0	2
Beauty of Bath ..	3	45	0	45	33	9	3	0	26.7	2
Bramley's Seedling ..	4	45	—	—	—	—	—	—	—	2
Newton Wonder ..	5	45	—	—	—	—	—	—	—	1-2
Worcester Pearmain	6	45	—	—	—	—	—	—	—	3-4
Beauty of Bath ..	7	45	—	—	—	—	—	—	—	2
Cox's Orange Pippin..	8	45	2	43	2	7	9	25	95.3	2‡
Bramley's Seedling ..	9	45	2	43	15	16	11	1	65.1	1
Newton Wonder ..	10	45	2	43	14	13	10	6	67.4	1-2
Worcester Pearmain	11	45	3	42	1	4	20	17	97.6	3
Cox's Orange Pippin..	12	45	5	40	0	4	12	24	100.0	2-3‡
Beauty of Bath ..	13	45	—	—	—	—	—	—	—	2
Bramley's Seedling ..	14	45	—	—	—	—	—	—	—	1-2
Newton Wonder ..	15	45	—	—	—	—	—	—	—	1-2
Worcester Pearmain..	16	45	2	43	0	0	5	38	100.0	3
Beauty of Bath ..	17	44	—	—	—	—	—	—	—	2
Bramley's Seedling ..	18	44	—	—	—	—	—	—	—	1-2
Newton Wonder ..	19	44	—	—	—	—	—	—	—	1
Worcester Pearmain..	20	44	—	—	—	—	—	—	—	3-4
Beauty of Bath ..	21	43	—	—	—	—	—	—	—	2-3
Newton Wonder ..	22	43	—	—	—	—	—	—	—	1
Newton Wonder ..	23	43	—	—	—	—	—	—	—	1
Beauty of Bath ..	24	43	—	—	—	—	—	—	—	2-3
Lane's Prince Albert	25	42	—	—	—	—	—	—	—	0-1
Beauty of Bath ..	26	42	0	42	12	15	10	5	71.4	2
Bismarck	27	42	3	39	1†	2†	11†	25†	—	—
Lane's Prince Albert	28	35	0	35	16	17	2	0	54.3	1
Bismarck	29	26	0	26	10†	2†	1†	13†	—	—
Lane's Prince Albert	30	34	13	21	8	11	2	0	61.9	1
Bismarck	31	32	2	30	5†	2†	3†	20†	—	—
Lane's Prince Albert	32	30	7	23	21	2	0	0	8.7	1
Bismarck	33	26	4	22	0	1	0	21	100.0	4
Lane's Prince Albert	34	6	0	6	6	0	0	0	0.0	0

‡ Injury to leaves due to caterpillars made a closer estimation impossible.

† Many of these trees having been sprayed, the amount of scab present was influenced by other factors.

* A rough classification of the intensity of attack in which 0 represents complete absence of scab and 4 the stage in which most of the leaves are sooty and curled.

TABLE II.

Percentage number of trees showing scab attack on the foliage.
Egerton, Kent: May, 1924.

Variety.	Rows (see Table I.)	Number of Trees examined.	Number of Trees attacked.	% Number of Trees attacked.
Annie Elizabeth ..	2	45	0	0.0
Lane's Prince Albert	28, 30, 32, 34	85	34	40.0
Bramley's Seedling ..	1, 9	64	29	45.3
Beauty of Bath ..	3, 26	87	42	48.3
Newton Wonder ..	10	43	29	67.4
Cox's Orange Pippin	8, 12	83	81	97.6
Worcester Pearmain ..	11, 16	85	84	98.8
Bismarck	33	22	22	100.0

SURVEY OF WALNUTS IN GREAT BRITAIN.

As Mr. Spence has pointed out in his valuable article in Vol. IV, No. 1 of this *Journal*, the Walnut is not grown on a commercial scale in this country, but single trees are common in all parts of the country and in the main the total crop from these though by no means small, is quite insufficient to supply the home requirements, and heavy importations from the Continent are made annually. Mr. Spence has described how home trees, in the main, have been produced from planted nuts and are, in effect, seedlings produced either from known or unknown parents. It is seldom that all seedlings give rise to good plants and the Walnut proves no exception to the rule, for, of the vast number of trees now cultivated in this country, some produce good nuts, some fair; and many produce quite inferior nuts.

In other countries it has been found possible to improve the walnut industry by working proved seedlings on to known stocks and thus by vegetative means to raise a number of trees which are known in advance to produce superior nuts. It cannot be claimed that the same method of procedure would hold good for this country, nor is it known whether the right kind of stocks for Great Britain are in existence. At any rate, some investigation of the matter seemed called for; and the Ministry was pleased to accede to the request of Mr. Spence, of Southport, and of Mr. Hatton, of the East Malling Research Station, for an inquiry. The County Horticultural Staff and the Ministry's Inspectors have been asked to collect during the present season samples of matured walnuts and to forward these to Mr. Spence, who has kindly and gratuitously offered to examine these for the Ministry and to report thereon. Each specimen will be treated separately and records kept as to the source of the nuts; age, height and spread of tree; approximate weight of the 1924 crop; approximate date when tree was in full leaf; approximate date of flowering; date when fruit was ripe; the distance from any other walnut tree or trees, and the local name of walnut, if any.

It is important that the enquiry should be made as comprehensive as possible, and that the samples should include nuts from a large number of trees, and even varieties which, from the appearance of the nuts, might hardly seem worth further consideration. Examination of such nuts may show characteristics of value for particular work; for example thinness of shell, absence of astringency, flavour, etc.

It is hoped that all persons with walnut trees of special merit will feel it a duty to co-operate with the Ministry in this first attempt to obtain a survey of the kinds of walnuts in cultivation. This survey precedes all attempts at development and improvement, and, if successful, paves the way for more rapid progress.

H.V.T.

26th August, 1924.